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ORIGINAL ARTICLES.

The Igneous and Associated Ordovician Rocks of Baxter's Bank, Radnorshire.

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I. Introduction.

THE area described in this paper is about 5 miles east of Rhayader and 4 miles north of Llandrindod Wells. The igneous rocks come to the surface in two localities, namely Baxter's Bank and Caerfagu Mill. The former is approximately half a mile north of the main road from Rhayader to Pen-y-Bont, whilst the latter is situated immediately to the south of the main road and about three-quarters of a mile south-east of the village of Nantmel.

The first reference to the igneous rocks of this area is apparently by Murchison (1)[1] in 1839, in his *Silurian System*. They are also mentioned by Ramsay and Aveline (2) in 1848. On the Ordnance Survey Map (3), published in 1850, they are indicated as "trap" forming three separate outcrops. Later in 1871, they were again referred to by Murchison (4).

The more important outcrop is that which occurs at Baxter's Bank. It has a peculiar form, and trends as a whole in a north-north-easterly direction for a distance of about a mile. The ridge attains its maximum width of about 230 yards opposite Baxter Farm. At the southern end of the outcrop, the igneous rocks are well exposed in Pen-y-bank Quarry. From this locality the outcrop extends as a narrow ridge for about 700 yards, until, directly west of Cae Meiriol

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[1] Numbers in parentheses relate to references at the end of the paper.

Farm, the ridge widens and here attains its maximum height of 1,181 feet. Also, at this point, the igneous rock divides into two parts and forms two outcrops, separated from one another by well-cleaved, black shales. Immediately north-east of the summit above Baxter, there is a well-marked groove or gap across the ridge, which may indicate the presence of a small fault. However, there are no outcrops at this point, and it is difficult to determine the exact relations of the igneous rock outcrop on each side of the gap. On the Ordnance Survey map (3), this gap is represented as a break in the continuity of the igneous outcrop, which is there indicated as occupying two separate areas. North-eastwards, the ground rises again, but not to the same height as farther south. Moreover, in this north-eastern part, there are three outcrops of the igneous rock, forming three distinct ridges, which are separated from one another by shallow depressions occupied by black shales. The mutual relations of the igneous rock and the intervening shales may be examined in the road section to the north of Bwlch-bryn-dinam Farm.

The igneous outcrop at Caerfagu Mill is about 1½ miles south-west of Baxter's Bank. The rock is exposed in an old quarry, and, as farther north, is in association with black shales. The outcrop here apparently occupies a small area, but as Murchison states: "It is covered by an accumulation of sandy detritus, including pebbles derived from the rocks of the adjoining district" (1).

II. PETROGRAPHICAL DESCRIPTION.

In hand specimens, the rock is remarkably uniform in texture, and fine grained. When fresh it is predominantly greenish blue, with dark freckles scattered throughout. The felspar crystals may often be seen either with the naked eye or by means of a hand lens. However, the rock is nearly always much decomposed, and in this state the original greenish-blue colour is lost. The weathered part exhibits yellowish-green, brown, and deep red tints, and may be as much as 2 inches thick.

Examination under the microscope shows that it is a decomposed olivine dolerite, and in every specimen examined all the original mafic minerals, with the exception of a few traces of biotite, have been completely decomposed, leaving behind well-defined pseudomorphs.

Before decomposition, the rock consisted of olivine, augite (or hypersthene), labradorite, ilmenite with accessory magnetite, biotite, rutile, and zircon.

The presence of olivine in the original rock is inferred from the fact that it now contains pseudomorphs possessing the outline which is so characteristic of that mineral. These pseudomorphs consist, in the main, of bastite and secondary quartz, the latter being allotriomorphic, exhibiting undulose extinction and often spherulitic structure. Serpentine showing mesh structure is also present, and

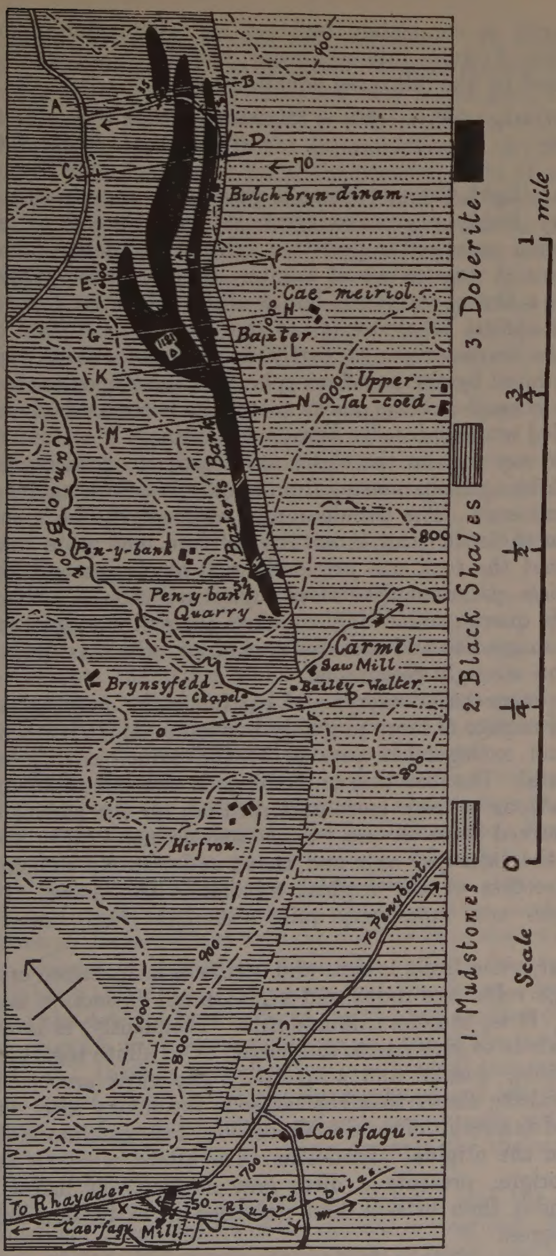

FIG. 1.—Map illustrating the Geology of the District around Baxter's Bank.

is often partly or completely replaced by calcite and magnetite. The alteration of olivine into serpentine, magnetite, and quartz may be represented by the following equation :—

$$\underset{\text{olivine}}{3(MgO,FeO)SiO_2} + 2H_2O + \tfrac{1}{2}O_2 = \underset{\text{serpentine}}{3MgO.2SiO_2.\,2H_2O} + \underset{\text{magne-tite}}{Fe_3O_4} + \underset{\text{quartz}}{SiO_2}$$

In ordinary light, the serpentine is pale green or yellowish green, and is very feebly pleochroic from yellowish green to almost colourless when examined in polarized light. The bastite contains a few inclusions of magnetite and calcite. Under crossed nicols it is seen to have a fibrous structure, but as all the fibres are not exactly parallel, the optical behaviour is not uniform. The arcuate cracks which are so characteristic of partly decomposed olivine crystals, are still exhibited by the pseudomorphs, and the serpentine is often very nearly isotropic. Wide cracks across the bastite pseudomorphs are often filled with confusedly fibrous serpentine.

No augite was seen in the slides examined, its presence in the original rock being again inferred from the shape and character of the secondary minerals. The pseudomorphs after augite are much less numerous in the rock than those after olivine, and it is inferred, therefore, that the rock was originally rich in olivine and poor in augite. These pseudomorphs after augite are generally composed of secondary quartz, exhibiting undulose extinction, together with calcite and magnetite and sometimes chlorite, which is deep green in colour and strongly pleochroic.

There are some pseudomorphs of bastite which may have been formed after augite, or more probably hypersthene. It has a fibrous structure and extinguishes parallel to the principal axis of the original crystal. The direction of the fibres is also the same, and the optical behaviour is much more uniform than for the bastite which has been derived from olivine. Some well-defined cracks are also parallel to the principal axis and these undoubtedly indicate the cleavage direction of the original mineral. The shapes of these pseudomorphs are, moreover, quite different from those after olivine.

The felspar, when fresh, is clear and occurs as lath-shaped crystals. It has a high refractive index and a maximum extinction angle of 30 degrees. It is, therefore, labradorite. Frequently, it is altered either as a whole to give rise to saussurite, or to albite together with calcite, epidote, quartz, and scapolite. The close association of albite and calcite shows that the latter is secondary after felspar, being formed as a result of the decomposition of the calcium molecule, anorthite, in the original labradorite. The albite, which is thus of secondary origin, presents a dirty grey surface; it has a lower refractive index than balsam, and possesses an extinction angle of about 14 degrees.

The rock is very rich in ilmenite, which occurs as small irregular grains or as large plates, distributed uniformly throughout. It is always found partly decomposed into leucoxene. In some cases it exhibits good examples of the so-called " bizarre skeletal forms ".

Magnetite is comparatively rare, and may be, in part, a primary mineral. There is no doubt that it is also present as a secondary mineral formed as the result of the decomposition of olivine.

Compared with the felspar laths, the pseudomorphs of serpentine and bastite already described are large, and the rock originally contained porphyritic crystals of olivine and hypersthene (or augite) in a groundmass of felspar laths, chlorite, and ilmenite. All the augite was probably not in this form, and if the chlorite and serpentine masses which fill up the spaces between the felspar laths have been derived from augite, then the original rock exhibited ophitic structure. In a few cases the felspar laths are seen to wrap round the pseudomorphs, thus producing fluxion structure.

The rock changes colour during decomposition from the original greenish-blue to a cream-coloured rock, with a tinge of green. The rock first of all becomes grey, and in this state the pseudomorphs of serpentine and bastite show up as black specks. After further alteration the rock becomes light yellowish green, then brown, and sometimes deep red, owing to the separation of limonite and haematite in various proportions.

In the Pen-y-bank Quarry the junction between the dolerite and the black shales which dip beneath it, is well exposed. Here, for a distance of about 2 feet from the contact with the shales, the dolerite presents characters which distinguish it at once from the main mass above. In hand specimens, the rock is predominantly cream coloured, with a few specks of green. It is extremely brittle, and is penetrated by numerous thin veins of quartz.

Under the microscope the rock is seen to be in a very advanced stage of decomposition. Felspar, which was abundant in the original fresh rock, is very largely decomposed into saussurite. Some of the felspar crystals which are partly decomposed exhibit a core of saussurite surrounded by felspar. The felspar is albite, which is probably secondary after labradorite as in the other cases.

The black shales in contact with the dolerite have also experienced a certain amount of alteration. This may be seen, for example, in the Pen-y-bank Quarry, and it appears that the shales immediately underlying the dolerite have suffered the greatest amount of change. Here the junction between the dolerite and the shales is sharp and quite distinct; there is no indication of a gradual transition. The shales in contact with the dolerite are hardened and silicified. The sedimentary rock becomes tough, massive, and breaks with a conchoidal fracture. Thin veins of quartz occur in the shales near the contact with the dolerite.

Although the boundary between the dolerite and the shales is well defined, the lower surface of the dolerite is irregular. Moreover, in several places, the shales have been crushed and violently contorted, so that the dolerite may rest on the upturned edges of highly folded shales. In these cases, the shale becomes a friable rock with puckered bedding planes, although ill-preserved graptolites may be extracted. In this type of altered shale there are numerous small crystals of pyrite, varying in diameter from 1 to 2 millimetres. The crystal form is invariably a combination of the cube and octahedron (100 and 111 faces). Pyrite is very common in many of the shales and slates of Central Wales, but generally occurs in the form of cubes. It is possible, therefore, that the unusual form of the pyrite crystals may have some connexion with the alteration which the shales have experienced.

Within the dolerite and near the contact with the shales below, there are occasionally oval masses about 8 to 9 inches long, which consist of brecciated shale. The shale fragments have been cemented together by silica, and the oxides and carbonate of iron.

III. Associated Sedimentary Rocks.

The associated sedimentary rocks may be divided into two main groups, namely, an upper group of coal-black shales and mudstones with grit bands up to 12 inches in thickness, and a lower group of grey-blue, thickly bedded mudstones. The boundary between these two groups is indicated in Fig. 1. There is a well-marked lithological difference between them, and the boundary can be traced without difficulty in the field. The grey-blue mudstones weather to pale brown tints, and so far have yielded no fossils.

The black shales and mudstones yield graptolites fairly abundantly. From Pen-y-bank Quarry, the following forms have been collected: *Orthograptus calcaratus*, var. *basilicus* Lapworth; *O. truncatus* Lapworth; *O. truncatus*, var. *socialis* Lapworth; *O. truncatus*, var. *pauperatus* Lapworth.

From a field west-south-west of Bwlch-bryn-dinam Farm, between the two more easterly dolerite ridges: *Mesograptus multidens*, var. *compactus* Lapworth; *Orthograptus calcaratus*, var. *basilicus* Lapworth; *O. truncatus*, var. *pauperatus* Lapworth.

These forms suggest that the black shales in contact with the dolerite belong to the zone of *Dicranograptus clingani* or *Pleurograptus linearis*, probably the former. The rocks are therefore of Bala age.

Westwards the black shale group is overlain by pale greenish-grey mottled mudstones, which make prominent features, immediately around and to the north of Nantmel village. These mudstones, in their lithological characters and stratigraphical position, recall the Abercwmeiddaw Mudstones described by Professor W. J. Pugh (5) at Corris. In the latter area, the Abercwmeiddaw Mudstones are immediately underlain by the black graptolitic shales of the Nod Glas. It is suggested that the black shales in the Baxter's Bank area correspond either to the Nod Glas or the highest beds of the Ceiswyn Group.

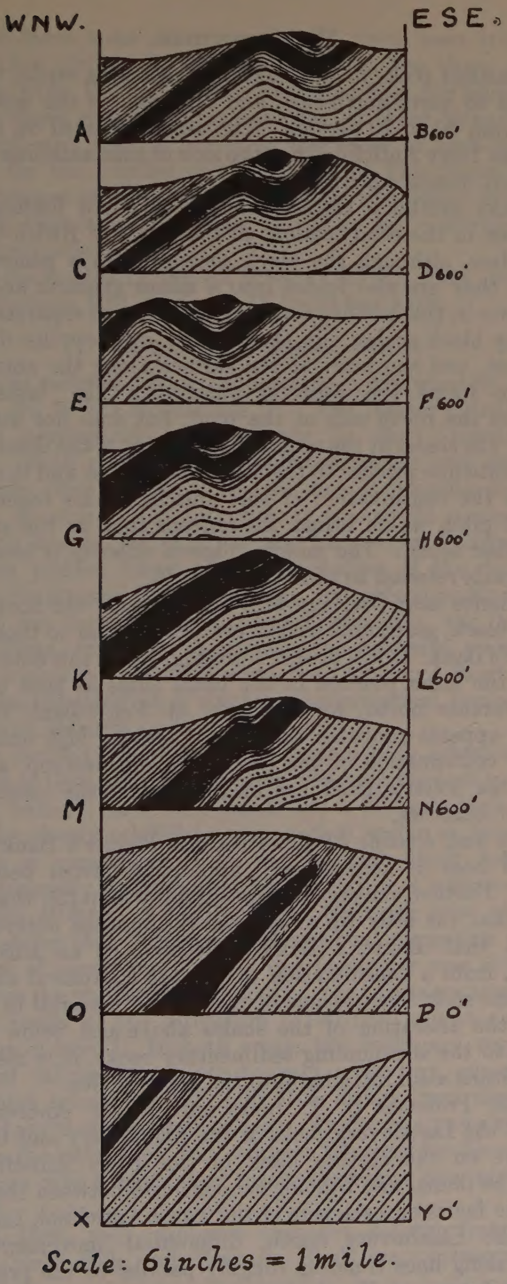

FIG. 2.—A series of horizontal sections across the area indicated on the Map (Fig. 1).

IV. STRUCTURE.

The stratified rocks in the Baxter's Bank area strike from south-south-west to north-north-east, and dip towards the west at angles varying from 30 to 70 degrees. The area is located on the western flank of the Towy Anticlinal, but the axis of that anticline is probably only a short distance farther east.

The rocks exhibit a certain amount of minor folding, which is clearly seen in the road section, to the north of Bwlch-bryn-dinam Farm. Here, although the black shales dip in a general westerly direction, they are also folded into a minor syncline and anticline. The dolerite in this locality forms three outcrops separated from one another by black shales. In the easterly outcrop the dolerite dips to the west, and reappears at the surface along the anticlinal axis, and there forms the westerly outcrop. The latter is well exposed on the north side of the road, but does not actually cross the road. The shales at the southern extremity of the dolerite indicate that the anticline pitches to the south-south-west and it is suggested that it is the continuation of this anticlinal axis together with a change of pitch which brings the igneous rock to the surface once more farther south. The middle ridge of dolerite is located on the synclinal axis referred to above (see Fig. 2).

The dolerite near Caerfagu Mill dips towards the north-west and occurs in black, graptolitic shales, precisely similar to those described at Baxter's Bank. It will be seen from Fig. 1 that this dolerite outcrop occupies the same position in the black shale as that of the main outcrop farther north, for example, at Pen-y-bank Quarry. It therefore appears probable that the Caerfagu Mill outcrop is the southerly continuation of the Baxter's Bank outcrop, although no trace of the dolerite itself has been found at the surface between these two localities.

Ramsay and Aveline (2) described the Baxter's Bank outcrop as "a small boss of ashy traps" appearing "from beneath black slates". Further, on the Ordnance Survey Map (3), the dip arrows indicate that the beds dip away from the igneous outcrop on each side, and that Baxter's Bank is located on an anticlinal axis. However, from a consideration of the petrographical characters of the igneous rock, the absence of pyroclastic material in association with it, the alteration of the shales above and below it, and its relations to the surrounding sedimentary rocks, it is clear that the dolerite forms a sill intruded into the black shales.

In 1925, Professor O. T. Jones and Mr. G. Andrew (6, 7, 8) described the Llandovery rocks of the Llandovery and Garth areas, which are on the eastern flank of the Towy Anticlinal farther south. The faunal and lithological contrasts between the shelly and graptolitic facies on each side of the Towy Anticlinal, indicate that, during the Llandovery epoch, differential movements were in progress along lines trending roughly parallel to the present strike. Professor Jones and Mr. Andrew have also shown that during the same period there were other movements along axes lying transversely to that strike. In the discussion on the three preceding papers (8, p. 416), Professor Jones suggested that the igneous rocks at Baxter's Bank might indicate another of these transverse axes of movement, and that it might be the same as that which was responsible for the overlap of the Rhayader Pale Slates over the Gigrin Mudstones at the eastern end of the Rhayader district. It will be seen that this suggestion is not so far confirmed by the present investigations.

At Pen-y-bank Quarry the sill is about 50 feet thick, but farther south, at Caerfagu Mill, it is only 15 to 20 feet thick.

V. Relation to Other Areas.

The igneous rocks of Llanwrtyd have been described by Dr. L. D. Stamp and Mr. S. W. Wooldridge (9). The Baxter's Bank dolerite appears to correspond fairly closely to the "intrusion" at Llanwrtyd. Both rocks contain albitized felspar and well-defined pseudomorphs after olivine. They are rich in ilmenite and exhibit porphyritic structure. The intrusion at Llanwrtyd occurs in black shales which are faulted against the Llanwrtyd Volcanic Series. These shales yielded fragments of graptolites of the diplograptid type to Dr. Stamp and Mr. Wooldridge, but subsequently Mr. K. A. Davies (10) has recorded *Orthograptus calcaratus*, var. *tenuicornis* Elles and Wood, from Penybanc near the intrusive mass. If the Llanwrtyd rock is not intruded along the Llanwrtyd Fault, it would appear to be intruded at a similar stratigraphical horizon as the Baxter's Bank dolerite.

Mr. H. G. Smith (11) has described certain basic intrusions, which outcrop east of Gelli Hill, Radnorshire. These intrusions include two rock types, namely, an olivine basalt and a diabase, both of which appear to be closely related to one another so far as mineralogical composition is concerned. Like the Baxter's Bank dolerite, the diabase is generally decomposed (11, p. 502), and contains pseudomorphs after olivine. Describing the Glan-oer type of diabase, Mr. Smith states that "there is an occasional suggestion of olivine in the shape of pseudomorphs and one particular case (1·2 mm. in length) places the matter beyond doubt; the substance is serpentine, and is the result of the alteration of olivine, almost certainly a variety poor in iron". In both areas, the rocks are very rich in ilmenite and calcite, the latter being a secondary mineral. The diabase, which occurs east of Gelli Hill, differs from the Baxter's Bank dolerite in that it contains augite. Augite was probably present originally in the latter rock, but owing to the considerable amount of decomposition which has taken place, there are now no traces of fresh augite.

It seems, then, very probable that the doleritic intrusions of Llanwrtyd, Gelli Hill, and Baxter's Bank are, petrographically, closely related.

VI. Age of the Dolerite Intrusion.

All that can be stated definitely concerning the age of the dolerite at Baxter's Bank is that it is post-Bala (later than the zone of *Dicranograptus clingani*), since the rock is intruded into sediments of that age.

At Gelli Hill, Mr. Smith (11) has shown that the diabase is post-Llandovery, and since there is a close similarity between the intrusive rocks of both areas, it may be that the Baxter's Bank intrusion belongs to the same period. Presumably, this may be true also of the Llanwrtyd intrusion. If this is so, then all these intrusions, as suggested by Mr. Smith (11), " are brought into line with those of the Shelve area, where Professor Watts has shown that the dolerites come into contact with and somewhat alter the *Pentamerus* limestones."

The close similarity between the various intrusions is of interest, as it tends to show that they have all been derived from the same magma which was comparatively rich in titanium.

In conclusion I wish to express my gratitude to Professor W. J. Pugh and Mr. J. I. Platt for much assistance and valuable advice during the course of the work. It is intended, subsequently, to describe the sedimentary rocks of this area in greater detail.

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(5) W. J. Pugh. *Q.J.G.S.*, lxxix, 1923, p. 508.
(6) O. T. Jones. *Q.J.G.S.*, lxxxi, 1925, p. 344.
(7) G. Andrew. *Q.J.G.S.*, lxxxi, 1925, p. 389.
(8) O. T. Jones and G. Andrew. *Q.J.G.S.*, lxxxi, 1925, p. 407.
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The Occurrence of Gypsum in the Tertiary Clays and Sandstones of Ecuador.

By George Sheppard, Ph.D.(Lond.), B.Sc., F.G.S., M.I.Min.E.

GYPSUM or selenite is one of the commonest " decomposition " minerals found in connexion with the exposed surfaces of the Tertiary rocks in southern Ecuador. With the possible exception of the coarser grits and conglomerates, the normal sandstones are usually veined extensively by sheets of this mineral ; it also occurs in a fibrous form (plates), in agglomerations of minute scalenohedrons, flake-like folia parallel to the bedding, and also in beautiful rosette-like or "stellate" groupings. In the typical clay shales or "gredas" the distribution of gypsum is not so general, though crystals or irregular groups of imperfectly shaped crystals occur on the weathered slopes or screes. In many localities, where a steep talus slope of shale forms the foot of a superimposing sandstone cliff, the scree itself is invariably covered with broken plates of gypsum in such profusion that from a distance it has the appearance of irregular masses of ice or glass. The platy form (which usually consists of parallel laminae with vertical fibres) is probably the most common and, in reality, each plate has been formed after the manner of a typical vein deposit.

There is little doubt that the chemical constitution of the shales, and the decomposition products derived therefrom through the agency of desert climatic conditions, are responsible for the universal distribution of the mineral upon all exposed rock surfaces. It is believed that the Tertiary sandstones themselves are the media for the recrystallization of the sulphate of lime, though it is possible that they contain also the necessary elements for the formation of the secondary gypsum.

According to Dr. Bosworth (*The Geology and Palaeontology of N.W. Peru*), the following observation is made in regard to the Tertiary strata of Peru :—

"In the desert weathering of the clay shales, much gypsum is produced. Most of it occurs in thin sheets composed of vertical fibres. Bedding planes, joint planes, crevices and fault planes, often are lined with these sheets and thin slabs, and pebbles, lenticles and calcitic veins may be encased in the same material. Occasionally there is so much of this substance that quantities of it have slipped down the slopes and resemble heaps of broken glass."

Walther[1] also states :—

"In desert regions ordinary rainfall is practically absent, so that there is no solvent action of the ordinary kind, but there is always a certain amount of water held in the rocks by capillary attraction. This is probably derived from the rare but violent rain storms and cloudbursts which occur even in the driest regions. Since the sun's heat is very strong and the air dry, this capillary water is drawn out and brings with it to the surface the soluble salts of sodium, magnesium, etc., with which many desert sands are saturated. Chemical reactions occur between these hot strong solutions and the constituents of the rocks, so that the latter are decomposed from within outwards.

"This process leads to cementing and solidification of some loose sediments, and colouring of many desert sands, usually some shade of red. There is often also efflorescence of soluble salts on the surface. During these reactions crystallization of salts may occur and this may cause splitting of solid rocks just as in freezing of water."

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[1] Walther, *Das Gesetz der Wustenbildung*, Berlin, 1900, chap. iii.

In connexion with the above, it should be noted that the climatic conditions prevailing in southern Ecuador do not follow the rule enunciated for true desert countries. More correctly the climate of the coast belt of Ecuador is sub-arid (though actually nearer the Equator than the vast desert regions of Peru and elsewhere). A certain amount of rain falls every year (January to March), and, in addition, frequent garuas or heavy mists occur along the coastal area throughout the remaining months of the year. Hence, though the dry season proper is characterized by a considerable amount of tropical solar heat, there is, in addition, superficial moisture in irregular quantities. It is evident, therefore, that in this part of the world the conditions are extremely favourable for chemical changes to be effected rapidly in connexion with the weathering and decomposition of rocks, especially in the case of Tertiary sandstones and shales. It has been noticed repeatedly that a fresh exposure of clay or shale is completely desiccated into a flocculent mass during the course of twenty-four hours. This, after the precipitation of a slight garua or mist upon the exposed material. Disintegration is a rapid process, and, as a consequence, it can be inferred that the conditions which govern the formation of gypsum and similar minerals are correspondingly very favourable.

A section presented by the coastal cliff at Ancon Point (Fig. 1) is of considerable interest. The section itself consists of about 20 feet of soft Tertiary sandstone, with little intercalated shale, being superimposed by 4 or 5 feet of Tablazo (a Quaternary deposit). An erosion surface separates the two formations, and, moreover, as can be seen in the figure, minor drainage channels are found in this plane of erosion, being connected below with the underlying joints in the sandstone formation. It is obvious, therefore, that prior to the deposition of the Tablazo deposit (actually a raised sea floor), the superficial drainage of the Tertiary land surface was carried off by small channels which naturally followed the planes of jointing in the underlying formations. Further, these open joints were gradually filled in by the mineralizing agency of the percolating waters from above, thus being presented at the present time as solid veins of gypseous and calcareous material. This process was still continued after the deposition of the Tablazo (Quaternary) formations, and as the latter are more or less of a highly calcareous nature, being derived principally from shelly beach detritus, it can be understood that the subaerial waters percolating from this deposit will be considerably charged with calcium carbonate. No gypsum of any kind is found in the Quaternary beds in the form of plates, crystals, or aggregations, but immediately below (in the Tertiary) the sheets of gypsum, more or less parallel to the stratification, can be observed "weathered out" from the parent sandstone rock.

The section can hence be subdivided into five distinct zones, each of which will be described in its relation one to the other.

(1) Tablazo (Quaternary) 4–5 feet.
(2) Erosion surface of the Tertiary.
(3) Tertiary sandstone with normal separation of platy gypsum.
(4) Zone of intense separation of gypsum.
(5) Zone of "rosette" groupings of gypsum.

(1) The Tablazo needs no further description beyond the fact that t is a Quaternary deposit and consists for the most part of loosely consolidated calcareous beach, or shallow sea-floor, material. Its texture, however, lends itself to easy percolation by atmospheric waters.

(2) The erosion surface between the Quaternary and the Tertiary deposits has an important bearing upon the problem under consideration, as the joint planes have obviously, in the past, formed drainage channels from the upper beds. Hence, as will be referred o below, the arched, or cusped, contour of the upper limit of (4) as been determined primarily through the agency of these channels.

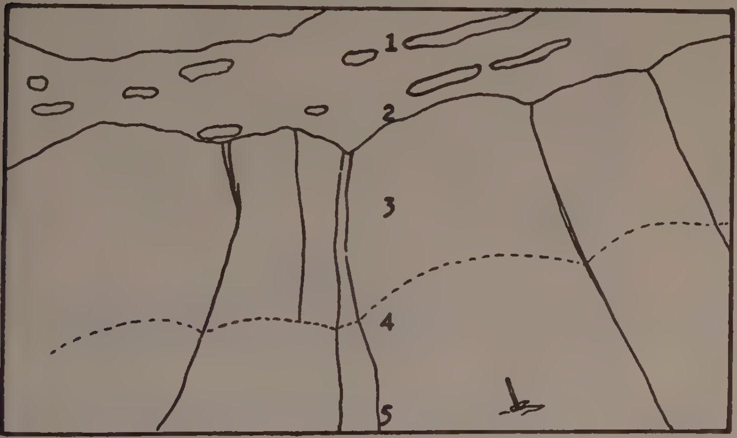

Fig. 1.

(3) This, the upper part of the Tertiary section, is typical of he sandstone in which there is a normal development of platy ypsum amongst the respective strata. The gypsum has no doubt esulted from the decomposition of iron salts in the sandstone, with consequent release of sulphuric acid. The latter, in its turn, unites ith the calcareous element of the rock with the result that gypsum sulphate of lime) is formed either in plates or in minute aggregations f crystals. The above process has, of course, been induced by the eculiar climatic conditions which prevail in this tropical area. t will be observed from Fig. 1 that the lower limit of this zone (3) s distinctly defined by a series of convex arcs, each being separated rom the other by joint-planes which extend upwards as far as the rosion surface of the Tertiary.

Below this (4) the sandstone for 3 or 4 feet is crowded with efflorescences of platy gypsum—a marked contrast from the sandstone immediately above.

(4) The upper part of this zone is defined by the peculiar cusped outline referred to above, and as can be seen by the great number of small plates of gypsum, this section of the sandstone rock is supercharged with sulphate of lime. The curved appearance of the line of demarcation bears a distinct relation to the presence of the joint planes which extend as far as the surface.

It is possible, therefore, that the joints have been the medium through which the atmospheric waters from above have transferred their quota of lime from the upper deposits to the lower. In the course of time the underlying porous sandstone beds have become heavily charged with sulphate of lime, with the result that a considerable exfoliation of this mineral has taken place as a consequence of local climatic influences. It is to be noted, also, that this zone of saturation traverses the strata irrespective of the dip of the formation.

(5) This zone of gypsum-bearing sandstone is probably more interesting than the others above referred to owing to the fact that there is a considerable development of sulphate of lime in the form of rosettes, some of which measure from 6 to 8 inches in diameter. Plates parallel to the bedding also occur in association with the rosette-shaped groupings.

This rosette type of gypsum appears to be a secondary form of exfoliating crystallization and has probably been caused in the following manner, through three principal stages :—

(*a*) In the more loosely consolidated strata of the lower beds the gypsum appears to have segregated into more or less spheroidal masses, which ophitically enclose the individual grains of sand. From a distance the gypsum impregnated rock has the appearance of a dark stain in the groundmass when contrasted with the adjacent exposed surfaces. It is possible to chip off flakes of this material (which is megascopically quite amorphous) and the sand grains are seen firmly embedded in the gypseous matrix.

(*b*) Crystallization of the whole spheroidal mass then begins, with the result that a series of cracks are formed irregularly radiating outwards from the centre.

(*c*) The cracks are then filled in subsequently with secondary gypsum which has probably been leached from the surrounding spheroid. These "solid" exfoliating cracks actually form the characteristic "rosette". The latter, however, only appears as a result of weathering, the gypsum itself being peculiarly resistant to the normal forces of tropical weathering.

SELENITE VEINS IN TERTIARY SHALES.

As referred to above, the natural occurrences of gypsum in the shales are not so common as in the associated sandstones. The shales, however, not infrequently contain concretionary structures, and these usually occur in defined bands parallel to the bedding. Upon exposure to the weather these concretions disintegrate rapidly, until finally the interior of the structure is simply an amorphous mass of varied oxides of iron, with fragmental gypsum. An advanced stage in the disintegration of a shale concretion can be represented as in Fig. 2. It will be observed that at least three varieties of iron oxide occur (yellow, brown, and red), all of which are in an amorphous state. The veins, which irregularly traverse the mass, consist of gypsum, with fibres at right angles to the direction of the vein. In the final stages of the decomposition of an iron concretion, the interior becomes powdery and gradually disappears, leaving behind a hollow shell made up of gypsum and iron oxide.

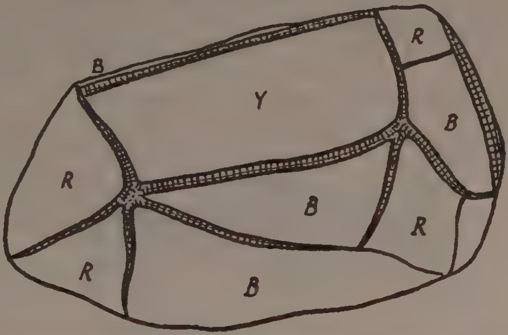

Fig. 2.—Cross-section of concretion. (Scale 1/2.) Showing partial decomposition with formation of selenite veins. R = red oxide of iron; B = brown oxide of iron; Y = yellow oxide of iron.

A typical vein, occupying a fault or crack in the shale, has a structure as illustrated by Fig. 3. The vein product itself appears to be the result of direct leaching from the shale rock. A chemical analysis made from the country rock in which the above veins occur is as follows:—

	%
Moisture	2·76
Silica	66·87
Iron oxide	5·44
Aluminium oxide . . .	15·78
Calcium carbonate . .	3·37
Calcium sulphate . . .	·94
Calcium phosphate . .	·52
Magnesium carbonate . .	4·32

The Surface and Sub-surface Weathering of Tertiary Shales and Sandstones (Ecuador).

The Seca Shales, occurring along the coast sections and inland to the east of Ancon, are probably of Upper Eocene age. They are of limited distribution and attain a thickness up to 400 feet. The shales are remarkably uniform and consist of compact dark grey to black homogeneous shale, for the most part unfossiliferous with the exception of Radiolaria and small serpula-like calcareous tubes. The weathered surfaces of the shale are invariably light grey to almost white in colour. The normal stratification has concretionary phases of various types. Exceptionally large pseudo-concretions up to 20 or 30 feet in length occur in certain horizons and although these have certain structural features of interest, their exact mode of origin has yet to be determined. Unlike most concretionary forms, they are non-nuclear, the bedding planes of the contiguous country rocks pass through the "concretion" conformably, and the cracks or minor joints in the structure are filled with a curious mammilated form of silica. Small iron oxide concretions also occur irregularly throughout, these being usually tabular and lenticular in habit. Well-defined layers of soft buff-coloured nodules are found parallel to the stratification and it is of interest to note that the latter concretionary forms are associated with zones of "soapy" shale, appearing to have been segregated from this latter material. Samples of unaltered Seca Shale (brought up as a core from a diamond drill at a depth of 350 feet) indicate clearly that the nature of this rock in its fresh state is quite different from its representative on the surface outcrop. The shale is a compact black rock, almost devoid of any evidences of stratification. It can be fractured only with difficulty, and even then does not show any tendency to break along the respective bedding planes. As will be seen from the following analysis, this shale is of a highly siliceous composition and contains very little carbonate of lime. On the other hand, the iron and aluminium oxides are fairly high for a shale of this type.

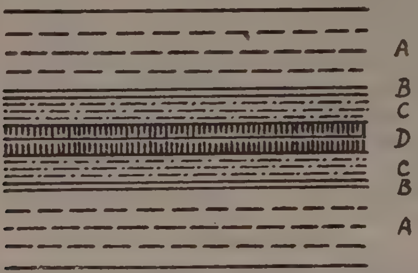

Fig. 3.—Type selenite vein. (Scale 3/1.) A = Tertiary shale; B = yellow iron oxide; C = brown iron oxide; D = selenite.

(1) *Chemical Analysis of Seca Shale* (*type*) *from Quebrada Engabao.*

	%
Moisture	9·24
Silica	78·19
Iron oxide and aluminium oxide	10·74
Calcium carbonate	1·59
Magnesium carbonate	·24

When exposed to the forces of weathering, however, the above shale changes in appearance very rapidly, and, indeed, the contrast is so great that the two specimens (one fresh and the other exposed) would not be recognized as being one and the same deposit. The weathered exposure of Seca Shales varies from light grey to white in colour. This, however, is purely superficial, and does not penetrate very deeply into the rock. The lighter colour (and softer texture) has no doubt been induced by the action of tropical conditions where the rapid evaporation of solutions brought to the surface of the rock (by capillarity) has caused the deposition of calcareous and other salts in the exposed laminae of the stratum. The weathered shales also exhibit thin-bedded strata, lines of brown oxide of iron concretions, small buff-coloured concretions (Analysis 2), zones of soapy textured shale (Analysis 3), and the exceptionally large pseudo-concretions (see above).

The small buff-coloured concretions are quite a feature in connexion with the more decomposed zones of the shale, and it is possible that they indicate a direct result of alteration and reprecipitation by atmospheric waters. A chemical analysis of the concretions above referred to is as follows :—

(2) *Chemical Analysis of Buff Concretions in Seca Shales.*

	%
Moisture	20·89
Silica	52·91
Iron oxide and aluminium oxide	16·57
Calcium carbonate . . .	5·94
Magnesium carbonate . .	3·69

Compared with (1), it will be seen that there is a considerable reduction in the silica percentage of the rock, though the oxides and carbonates are correspondingly increased.

The typical buff colour of the concretion has a distinctly "dolomitic" appearance, and this, in itself, may be due to the concentration of magnesium carbonate in the structure. The above concretions are invariably found associated with zones of shale which have a peculiar (yet characteristic) "soapstone" appearance. Quite commonly this material has a waxy texture, and can be indented with the finger-nail after the same manner as bentonite. From their field occurrence, it is probable that these aggregations represent a further stage of "leaching" from the true shale through the intermediate phase of the "soapstone". On analysis the latter is found to consist of :—

(3) *Chemical Analysis of "Soapstone" Shale found in association with Buff Concretions.*

	%
Moisture	16·44
Silica	58·36
Iron oxide and aluminium oxide	24·40
Calcium carbonate . . .	·51
Magnesium carbonate . .	·29

From the above, it will be observed that, compared with Analysis (2), both the calcium and magnesium carbonate constituents are considerably reduced whilst the iron and aluminium oxides are relatively high.

Disintegration of shale formations, with consequent denudation, is especially rapid under the influence of the unusual climatal conditions normally associated with certain tropical regions. Long "dry seasons" alternated by wet intervals of great intensity have a great destructive effect upon all exposed rock surfaces. Constant desiccation in the heat of the sun for at least nine months of the year renders superficial strata adaptable for rapid disintegration by water. As referred to above, a fragment of Tertiary shale (after being thoroughly moistened by a heavy shower) will be resolved from the solid rock to a flocculent mass of amorphous clay during the course of twenty-four hours. Apparently the action of the water, in filling all the capillaries and minute cracks of the sun-baked surface, causes a swelling of the superficial layers of the formation, with a consequent "flaking" or degradation of the material. Successive applications of moisture, alternated by periods of intense solar heat, cause a repetition of this process, with the result that the exposed rock is materially reduced in a comparatively short space of time.

The following observations were made in connexion with an exposed outcrop of Seca Shales during the early months of last year (1926). "Before the advent of the rainy season the exposure consisted of a clean bedding plane, this being slightly jointed vertically in a polygonal form. The joints, however, were not open, and appeared as slight cracks only upon the surface. The shale itself had a light grey appearance, this being characteristic of the weathered formation. During the first part of the rainy season about 9 inches of rain fell from the 24th January to the 12th February, and although the maximum temperature in the shade never exceeded 90 degrees F., rocks exposed to the direct sunlight were heated to a considerable degree. Following the interval of rainfall quoted above, the bedding plane under observation was almost unrecognizable owing to the lithological and structural changes which had taken place. The minor cracks which, before the rain, were barely discernible then consisted of prominent raised ridges (about ½ in. in width). The latter also formed peripheral ridges which succeeded in a concentric manner towards the centre of the original polygonal area. The central zone, in itself, was slightly 'domed' as a result of the minute exfoliation of the weathered formation. The 'wash' or detritus removed during the disintegration of this surface took the form of a peculiar grey mud of a thin soap-like consistency."

Fig. 4 (*a*, *b*, and *c*) illustrates the successive stages in the degradation of a Tertiary shale block during a short interval of time under ideal tropical conditions. It is obvious that the presence of capillary water in the superficial cracks, pores and crevices of a shale rock causes a reaction similar to that induced by the behaviour of water when freezing. At the same time, the various processes of mineral leaching which take place during the rapid evaporation of the capillary waters (being, in effect, hot solutions) assist in the further destruction of the primary rock,

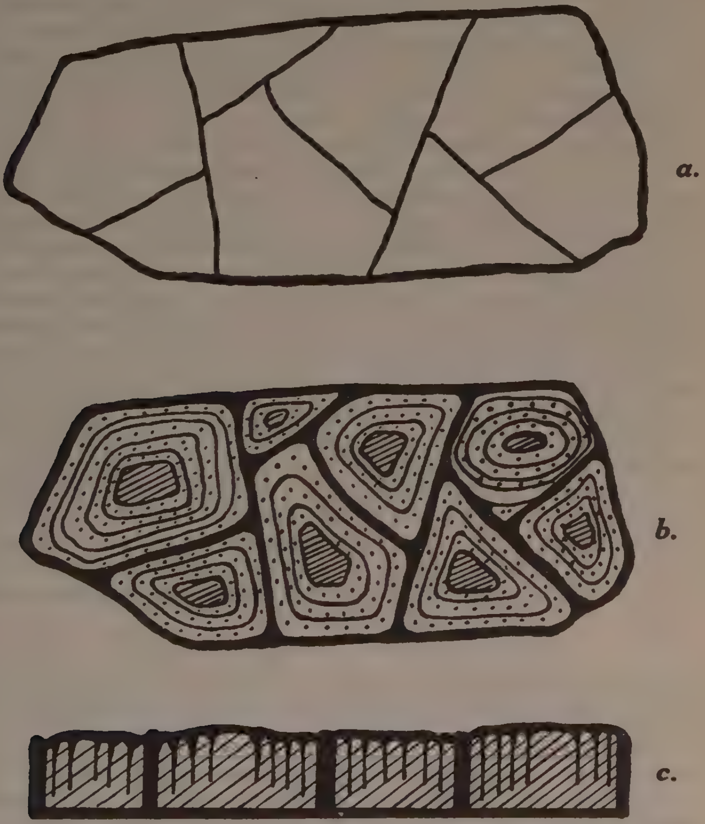

Fig. 4.—(*a*) Shale slab traversed by fine cracks. (*b*) As above (after period described in the text). (*c*) Cross-section of (*b*), showing " domed " nature of the " solid " joints, and isolated blocks.

From the above (*b* and *c*) it will be seen that subject to further rains and heat the small blocks separated by the raised joints will ultimately become detached from the original mass and the degradation of the whole slab will be complete.

The Sub-surface Weathering of Tertiary Shales.

In order to investigate this problem two pits were excavated from 15 to 20 feet in depth. In both cases the surface deposits consist of

Tablazo formation (Quaternary), which, however, only attain a thickness of about 3 feet. The latter rests unconformably upon normal Tertiary formations, dipping at 15 degrees to the east, these consisting for the most part of homogeneous clay shales with occasional intercalated beds of sandstone. The latter have a lenticular habit, and do not persist with regularity. The Tablazo covering is calcareous in composition, but when subjected to the usual forces of weathering the rock is resolved into a soft black earth, the latter presumably being caused by the roots of vegetation in conjunction with atmospheric waters.

Chemical alteration in the formation does not persist for more than a depth of 15 feet, and although concretionary structures may occur at greater depths, they cannot be attributed to the action of percolating water from above. Both red and brown oxides of iron occur commonly and whilst these separations are normally associated with the small faults and joint planes they not infrequently stain the country rock itself with the respective colours. It is to be noted that the yellow oxide does not apparently occur at depth below the surface, but is probably due to direct contact with the atmosphere.

The brown oxide, however, has a tendency to form in lenticular bands of flat concretions, usually occurring as a reduction from a stratum charged with the red variety.

Gypsum veins occur sporadically (as a rule parallel to the bedding planes), but they are invariably associated with some form of oxide of iron.

Recent Work on the Phacopidae.

By F. R. Cowper Reed, Sc.D., F.G.S.

SINCE the publication of the paper by the present author[1] in 1905 on the Classification of the *Phacopidae*, a considerable advance has been made in our knowledge of this family as a result of further and better material being obtained, and of new discoveries in different parts of the world. Many new genera and subgenera have been instituted, and modifications or limitations of some of the old terms have been introduced by various authors. The work of Wedekind, Clarke, Rud. and E. Richter, and Kozlowski has specially dealt with questions of classification, but there is still a considerable amount of diversity in the usage and application of the generic and subgeneric names.

The morphology of the head-shield of *Phacops* with special reference to the distinguishing features of its subgenera, has been recently discussed by the Richters[2] in connexion with the Uppe

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[1] Reed, Geol. Mag., Dec. V, Vol. II, 1905, pp. 172–8, 224–8.

[2] R. and E. Richter, "Trilob. d. Oberdev.": *Abh. preuss. geol. Landesanst.*, N.F., Heft 99, 1926, pp. 126–235.

Devonian trilobites, and the ontogenies of the *Phacopidae*, particularly in connexion with their relation to the *Paradoxidae* have been the subject of examination by Raw,[1] who has drawn attention to certain remarkable points of similarity. Incidentally, in discussing the segmentation of the head-shield of trilobites in general, Henriksen [2] has alluded to the fact that the rostrum (= epistome) has apparently coalesced with the doublure which thus forms a more or less broad band in front of the marginal suture. Raw (op. cit., p. 320, pl. xv, fig. 3) likewise states that " the two pareiae (= free-cheeks) in the *Phacopidae* are ankylosed with the epistome and the connecting sutures between these parts are not traceable ". The Richters (op. cit., p. 128) likewise notice this feature.

The Richters (op. cit., pp. 131, 200) have adopted the division of the family into two subfamilies, the *Phacopinae* and *Dalmanitinae*, which were proposed by the present author in 1905, and they have revised the Upper Devonian representatives of these divisions, instituting several new subgenera. Thus, in the genus *Phacops* they recognize the following subgenera : *Phacops* Emmrich, 1839, *Nephranops* subgen. nov., *Cryphops* subgen. nov., *Trimerocephalus* McCoy, 1849, and *Dianops* Richter, 1923, while in the *Dalmanitinae* they mention two genera *Phacopidella* Reed, 1905, and *Asteropyge* Hawle and Corda, 1847 (= *Cryphaeus* Green, 1837, non Klug, 1833). In *Asteropyge* they recognize three subgenera : *Asteropyge* Hawle and Corda, *Comura* subgen. nov., and *Metacanthus* Hawle and Corda, 1847.

It will be convenient to discuss the recent generic and subgeneric terms in their chronological order of institution before reviewing the modern usage of the older or well-established names.

PART I.

Recently established Genera and Subgenera.

(1) *Metacryphaeus*. Reed, Geol. Mag., Dec. V, Vol. IV, 1907, p. 168.

This name was suggested for a group of species occurring in the Bokkeveld Beds of South Africa, and it was considered to comprise such species as *Ph. caffer* Salt., *Ph. ocellus* Lake, *Ph. impressus* Lake, *Ph. callitris* Schwarz, *Ph. ceres* Schwarz, and *Ph. gydowi* Schwarz. The characters mentioned were " the tendency for the second pair of lateral furrows of the glabella to be reduced and not to enter into the axial furrows, resulting in a more or less complete fusion of the first and second lateral lobes of the glabella ". The genal angles in these species, however, vary greatly, some being rounded, others angular, or produced into long spines or furnished with small " pseudogenal " spines. It was not clearly stated which species was chosen as the type of *Metacryphaeus*, and the one first mentioned,

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[1] Raw, *Q.J.G.S.*, vol. lxxxi, 1925, p. 279.

[2] Henriksen, " Segmentation of Trilob. head " : *Medd f. Dansk geol. Foren.*, Bd. 7, 1926, p. 23.

Ph. caffer Salt., is now [1] regarded as a true *Cryphaeus* [= *Asteropyge*]. The group undoubtedly embraced a somewhat miscellaneous series of species which in the light of further knowledge ought to be dissociated and distributed amongst other better limited groups.

Clarke (1913, pp. 147, 152) objected to the name on the ground that it suggested a "morphologic intimacy" with *Cryphaeus*, but he recognized the group as constituting a natural subdivision of his larger group *Mesembria*, and he would place in it his new genera *Calmonia*, *Proboloides*, and *Pennaia* (see below). The South African species, *Ph. ocellus*, was recognized by Clarke in the Brazilian Devonian, but he referred it to his new genus *Calmonia*. It should be remarked that Lake (1904, p. 208) had previously stated his belief that *Ph. ocellus* and *Ph. impressus* should be separated to form a new subgenus, and it was with this in his mind that the present author suggested the name *Metacryphaeus*. Thus it appears that it has the priority of Clarke's name *Calmonia* if *Ph. ocellus*, the second species mentioned in 1905 by the present author, is taken as the type instead of *Ph. caffer*. However, it has not been generally accepted as a subgeneric title, but as indicating a type of structure common to several subgenera or genera. Kozlowski (1923, p. 54) recognized it as a group which included *Proboloides*, and adopted Clarke's view. The latter thus defined *Metacryphaeus*: "A group in which the cephalon is low and smooth, the glabellar furrows faint, barely reaching the shallow (or deep, *Acaste devonica*) dorsal furrows, the glabella evenly depressed, the cheeks rounded with very small exsert genal spinules, and the eyes small, sparse-lensed and well forward, and the whole shield greatly compacted . . . The pygidium bears, almost without exception, a fringe of marginal spines or lappets equivalent in structure but not similar in number to those of *Cryphaeus*." Apparently, then, it may be concluded that *Metacryphaeus* signifies a group of genera rather than a genus or subgenus, and therefore does not clash with *Calmonia* used strictly in a generic sense.

(2) *Anchiopella*. Reed, Geol. Mag., Dec. V, Vol. IV, 1907, p. 169.

The type which was chosen for this special group and exemplified by *Dalmanites anchiops* Green, was *Ph. cristagalli* (Woodw.), with *Ph. africanus* Salt., *Ph. arbuteus* Lake, and *Ph. acacia* Schwarz as other members of the group. Clarke (1913, p. 152) regarded this group as another subdivision of his group *Mesembria*, and therefore equivalent in rank to *Metacryphaeus*, and he stated that it "presents more tumid and coarsely pustulose glabellas [than *Metacryphaeus*], with deep dorsal furrows, but with the glabellar furrows still shallow and not entering the dorsal, the lobes more or less fused, the cheeks still rounded, spined, the eyes reduced and without basal grooves, the border without frontal ornament". The present author had

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[1] Reed, *Ann. S. African Museum*, vol. xxii, 1925, p. 139.

characterized it (1905, p. 169) (1) by the possession typically of eight segments in the pygidium, though of only five pairs of ribs as a rule on the lateral lobes; (2) by the presence of median spines on the axis of the thorax and the pygidium; (3) by small instead of stout and long genal spines; (4) by the less pronounced coalescence of the 1st and 2nd lateral lobes of the glabella; (5) by the prolongation of the pygidium into a more or less pointed mucro; (6) by the absence of marginal spines on the pygidium.

Clarke has figured one of the characteristic South African species, *Ph. acacia* Schwarz, from the Falkland Isles (1913, p. 116, t. v, figs. 5–9). The old established South African species *Ph. africanus* Salt. is now definitely proved to belong to *Anchiopella*, and the present author uses the name as of subgeneric rank (1925, p. 122) in the genus *Dalmanites*. Kozlowski also uses it (1923, p. 51, pl. ii, figs. 11–14), but as a subgenus of *Acaste.*

(3) *Eutrimerocephalus.* Gortani, 1907, *Mem. Accad. Scien. Instit. Bologna*, ser. vi, tom. iv, 1907, p. 229.

Type-species: *Trimerocephalus* [*Trinucleus*] *laevis* (Münst.). *Beitr. z. Petrefakt.*, v, 1842, t. x, fig. 6. Devonian.

Gortani proposed the name *Eutrimerocephalus* as a subgenus of *Trimerocephalus* characterized by the complete absence of eyes, and he included in it several other species in addition to the type. But according to R. and E. Richter (1923 (1), pp. 69–71), he trusted to the figures of earlier works and was thereby led astray, so that his identifications of species and his subgeneric divisions are erroneously based. Moreover, according to the international rules of zoological nomenclature, *Eutrimerocephalus* is inadmissible, and the Richters (op. cit., 1926, p. 168) use the name *Trimerophalus* in an equivalent subgeneric sense. It is needless to enter into the question of the specific reference of the various forms described by Gortani, but the Richters put them all either in the subgenus *Trimerocephalus* or in one of their new subgenera of *Phacops*.

(4) *Microphthalmus.* Gortani, 1907, op. cit., p. 229.

Type-species: *Ph. cryptophthalmus* Emmrich, 1845 (*Uber die Trilobiten, Leonh. v. Bronn's N. Jahrb. f. Miner*, etc., pp. 27–40. Gortani, op. cit., p. 232, t. i, figs. 20, 21, t. ii, figs. 20, 21).

Gortani chose the name *Microphthalmus* for a subgenus of *Trimerocephalus* in which the eyes are reduced and have few facets. The Richters (op. cit., 1923, p. 70, footnote) point out that the name is pre-occupied, and they at first put all the species which he mentioned in the subgenus *Trimerocephalus*, but recently (op. cit., 1926, p. 157) they have established the subgenus *Cryphops* (see below) for the true *Ph. crytophthalmus* Emmr., 1844, and for some other species.

(5) *Reedops.* R. and E. Richter, 1925, *Senckenbergiana*, Bd. vii, Heft 6, p. 243 [= *Reedia* Wedekind, 1911, *Zeitschr. deut. geol. Gesell.*, Bd. lxiii, p. 322, non *Reedia* Ashmead, 1904].

Type-species: *Phacops bronni* Barrande.

Wedekind, who gave the pre-occupied name *Reedia* to this group in 1911, further defined and illustrated it on a subsequent occasion (1914, pp. 35, 36, figs. 5, 6). The Richters, who have suggested the name *Reedops*, recognize in it a well-defined genus or subgenus. The head-shield is stated to have a similar contour as in *Phacops* s. str. The meso- and pleuro-occipital portions of the occipital segment are similarly defined. But the frontal limb (= border) under the glabella is only a fine raised band, while the subcranidial furrow is absent in this region, being only developed on each side towards the posterior angles of the head-shield. The doublure, therefore, in the middle is in contact without interruption with the frontal limb and has a broad anterior convex portion and a concave posterior portion with its posterior outline forming a convex curve and the sides narrowing posteriorly, being concave behind and not reaching back to the posterior angles of the head-shield. The glabella usually projects strongly over the frontal limb, and the eyes are frequently much reduced or may be quite absent. Kozlowski (1923, p. 28) is not inclined to accept *Reedia* as a distinct genus or subgenus, attributing no importance to the form of the cephalic doublure or to the continuity of the subcranidial furrow. Moreover, the rarity of the occasions on which the lower surface of the head-shield can be studied makes the use of these features of little practical value in his opinion. But if the features which Wedekind describes are of sufficient morphological and taxonomic importance, the fact that they cannot be often observed does not justify us in ignoring them in other cases. From the structural features emphasized by Wedekind there seems to be sufficient reason in recognizing this subgenus in spite of Perna (1915, p. 50) also rejecting it. The Richters (op. cit., 1926, p. 128) are inclined to retain the name as of subgeneric value.

(6) *Glockeria.* Wedekind, 1911, *Zeitschr. deut. geol. Gesell.*, Bd. lxiii, p. 323.

The type of this genus or subgenus chosen by Wedekind was *Ph. glockeri* Barr., and he mentioned *Ph. trapeziceps* Barr. and *Ph. bulliceps* Barr. as also belonging to it. But it is unfortunate that the present author had previously in 1905 chosen *Ph. glockeri* Barr. as the type of his *Phacopidella*, though a mistake was then made in including in it the well-known English but non-allied species *Ph. downingiae* Murch., and also in attempting to substitute the name *Phacopidella* for the preoccupied name *Acaste* by considering them to be equivalent. The original type of *Acaste* being *Ph. downingiae*, there has been great confusion owing to the erroneous inclusion within the subgenus *Phacopidella* of more than one subgeneric type of phacopid. Perna (1915, p. 50), however, rightly distinguished *Acaste* and *Phacopidella*. McLearn (1918, p. 33) and Richter (1923 (2), p. 137) have pointed out that the name *Phacopidella* has priority over *Glockeria* and must be retained for trilobites of the type of *Ph. glockeri*, though its extended application to those of the true *Acaste* type is to be deprecated. The Richters consider, moreover, that the structural characters of *Ph. glockeri* are of sufficient importance to give *Phacopidella* rank as a genus, and the name is thus used by them for certain Upper Devonian trilobites (op. cit., 1925, p. 200). They have also re-established *Acaste* as distinct and worthy of subgeneric rank. With regard to *Ph. trapeziceps*, which Wedekind subsequently (1914, p. 38) named as the type of his genus *Glockeria*, it is included by the Richters (op. cit., 1926, p. 200) in *Phacopidella*, but if the species is considered sufficiently distinct to be subgenerically separable from *Ph. glockeri*, the name *Glockeria* will have to be revived.

(7) *Denckmannia*. Wedekind, 1911, op. cit., p. 323.
= *Denckmannites*. Wedekind, 1914, *Abh. preuss. geol. Landesanst.*, N.F., Heft 69, p. 38.

The name *Denckmannia* was proposed by Wedekind for a subgroup of his genus *Glockeria*, with *Ph. volborthi* Barr. as its type. In it the eyes are small instead of large, and do not rise above the cheeks, the frontal limb is completely in front of the glabella, for the glabella does not project and is not inflated, while its anterior end makes a small angle with the general plane of the head-shield. The basal lateral furrows do not unite in the middle, and the first and second lateral furrows are only feebly indicated. These distinctions were thought to be of such slight value or constancy, that Richter (1923 (2), p. 140, and 1925, p. 200) and Kozlowski (1923, p. 29) would include it in *Phacopidella*. But this stretches the definition of the latter genus to an undue extent and can hardly be accepted as satisfactory.

The name *Denckmannia* was changed by Wedekind in 1914 into *Denckmannites* because he found that it was preoccupied and he added that he differed from *Glockeria* sens. str. by the absence or small size of the eyes and the absence of palpebral lobes.

Perna (1915, p. 51) considered that *Denckmannia* was "fairly well characterized and its separation from *Phacops* s. str. most desirable". He summed up its subgeneric characters as follows: "Head flat. Basal and neck-furrows well developed, frontal and middle ones faintly. Eyes at the anterior extremity, badly developed. Subcranidial groove absent. Rostral shield (= subcranidial doublure) broad and flat. Silurian. Devonian." He described two new species from the Upper Devonian of the Urals, *D. limaria* (op. cit., p. 55, pl. ii, figs. 2–8) and *D. revertens* (op. cit., p. 56, pl. ii, fig. 9). The latter is allied to *Ph. lotzi* Drev., according to Perna, but Richter

(1923, p. 140) includes both in one species, *limaria*, and describes (1923, p. 142, figs. 3–7) a new species allied to it as *Phacopidella diensti* from Oberscheld, and in 1926 this opinion is maintained by the Richters and the subgeneric name *Denckmannia* or *Denckmannites* is regarded as unnecessary, the species being all capable of inclusion in *Phacopidella*.

(8) *Pterygometopidella*. Wedekind, op. cit., 1911, p. 324.

The type of this subgenus is *Ph. quadrilineata* Ang.[1] from the Silurian of Gotland, a species which Lindström[2] considered to be allied to *Ph. stokesi* M. Edw. and *Ph. musheni* Salt. The lateral portions of the frontal lobe of the glabella are extended and pass into the border of the head-shield, but are cut off from the glabella by the facial sutures. The subgenus seems identical with *Portlockia* McCoy (see below).

(9) *Calmonia*. Clarke, 1913, *Foss. Devon. Parana, Mon. Serv. geol. e Miner. Brasil*, vol. i, 1913, p. 119.

The type-species is *C. signifer* Clarke (op. cit., p. 121, t. vi, figs. 1–12, t. vii, figs. 20, 21) from the Lower Devonian of Brazil. Clarke states that the essential structure is that of *Acaste* sens. str. But the pygidium has six spinules on each side and a stout terminal spine and the type species has a " pseudo-genal " spinule at the rounded genal angle as in *Proboloides* (q.v.), and a short rostral projection in front of the glabella. More than one Bokkeveld species[3] from South Africa is now recognized as referable to *Calmonia*, including *Ph. ocellus* Lake, *Ph. impressus* Lake, and *Ph. callitris* Schwarz. No concise summary of the generic or subgeneric characters was given by Clarke, but its distinctive features are well shown in the type-species *C. signifer*. Kozlowski (1923, p. 31) has put *Calmonia* as a subgenus of *Acaste*.

(10) *Proboloides*. Clarke, 1913, op. cit., pp. 135–8.

The characters of this Lower Devonian genus are well exhibited in the type-species from Brazil (*Pr. cuspidatus* Clarke, op. cit., p. 135, t. viii, figs. 13–19), though no separate diagnosis of the genus is given. The cephalon is of the *Mesembria* type of structure; the frontal limb and doublure are produced into a median rostral spine quite independent of the glabella which is rounded in front; the genal angle is rounded, but bears a spinule, and there is also a supragenal (parial) spinule arising from the lateral margin of the free cheek just in front of the point of section by the facial suture. The pygidium is incompletely known. A species *Pr. ensifer* Reed,[4] has been recently described from the Bokkeveld Beds, but it lacks the lateral (parial) spinule. In *Pr. cottreaui* Kozlowski (1923, p. 53, pl. ii, figs. 10, 10*a*) the frontal rostrum seems to have the same origin as in the type-species, but in the other Bolivian species, *Pr. glabellirostris* Kozlowski (1923, p. 52, pl. ii, figs. 9, 9*a*), this rostrum is a projection of the glabella itself and lies behind the conjoint facial sutures, this being a completely different structure, and we may doubt if the reference to this subgenus is correct.

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[1] Angelin, *Palaeont. Scand.*, 1854, p. 12, t. ix, fig. 5.

[2] Lindström, *Ofvers. k. vet. Akad. Förhandl.*, 1885, No. 6, p. 43.

[3] Reed, *Ann. S. African Mus.*, xxii, 1925, pp. 149–56.

[4] Reed, op. cit., 1925, p. 136, pl. viii, figs. 4, 4*a*–*d*.

The presence of a supra-genal parial (antero-lateral) spine in front of the lateral (posterior) branch of the facial suture is a remarkable feature which has been interpreted as reversional in character, recalling Cambrian ancestors, as Clarke (op. cit.) and Walcott[1] have pointed out. Further comments of this supposed case of reversion or atavism have been subsequently made by Clarke[2] in connexion also with the development of axial and intergenal spines in Devonian and other late trilobites, and he is led to regard them as " latent characters never actually lost, but only submerged for longer or shorter time by the interpolation of inhibiting factors ".

(11) *Pennaia.* Clarke, 1913, op. cit., p. 132.

Type-species: *Pennaia pauliana* Clarke (op. cit., p. 133, t. vi, figs. 18–25), Lower Devonian, Brazil.

Clarke does not give a concise definition of this genus, but says: " In general aspect it is distinctly more phacopidean than *Calmonia* in respect, first, to the cephalon in which all parts are more compacted and condensed; second, in the thorax where the axis is relatively much broader than the side lobes, while the ends of the anterior segments are rounded rather than lanceolate; third, in the pygidium which is again phacopidean in its small size and sparse segmentation. On the other hand the head still displays the lobate structure of the *Metacryphaeus* group in a reduced or more obsolescent condition of lobation. To the phacopidean peculiarities of the thorax just mentioned and of the pygidium as expressed in its form, size, and segmentation is to be added this indicial character; the margin of the pygidium is fimbriate, bearing three flattened spinules on each side." The presence of these spines in this Acastid pygidium seems to be the most typical and important feature. In addition to the Brazilian representative of the genus in which it was founded a South African member of it has been since described[3] as *P. africana* Shand (emend. *P. africanoides* Reed, 1925, op. cit., p. 158), and it has been determined[4] that the species described as *Ph.* (*Cryphaeus*) *gydowi* by Schwarz in 1906 which also comes from the Bokkeveld Beds possesses all the main characteristics of the genus. It is probable that the Bolivian species *Acaste verneuili* D'Orb., described and figured by Kozlowski (1923, p. 48, pl. iv, figs. 1–6), which has two spinules on each side of the pygidium, should also be referred to it. Kozlowski (1923, p. 31) put *Pennaia* as a subgenus of *Acaste*. But like *Calmonia*, it seems to have affinities with the *Dalmanitinae*, and may belong rather to that subfamily.

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[1] Walcott, *Cambrian Geology and Palaeont.*, iii, No. 5, Cambrian Trilobites, Smithsonian Miscell. Coll., v, 64, 1916, p. 237.

[2] Clarke, 16*th Rept. New York State Mus.* (*for* 1919), 1921, pp. 73–8.

[3] Shand, *Trans. Geol. Soc. S. Africa*, vol. xvii, 1914 (1915), pp. 24–8, pl. vi.

[4] Reed, op. cit., 1925, p. 157, pl. ix, figs. 7, 7*a*, pl. xi, fig. 2.

(12) *Phacopina*. Clarke, 1913, op. cit., pp. 149–51.

The type-species, *Ph. brasiliensis* Clarke,[1] was described in 1890 from the Lower Devonian of Brazil. The cephalon is singularly compacted, the glabella is elevated and somewhat protuberant, with the lateral furrows almost obsolete, the first two rarely showing except on compression or on casts; the cheeks are rounded and drooping and without spines; the eyes are relatively large. The pygidium is relatively large and heavy, multiannular, without spines and blunt at the extremity. McLearn [2] adopts *Phacopina* as a genus, stating that all but the third pair of lateral glabellar lobes are fused together, and that the species "lacks the broad expanding glabella with greatly reduced third pair of side-lobes of the *Phacopinae*, and also differs from the coeval Phacopinids by having a much-depressed and non-tuberculose glabella." But owing to his mistaken use of the author's generic name *Dalmanitina*, as partly equivalent to *Phacopidella* (see below), he classes it with the Dalmanitinids.

Clarke recognizes several North American early Devonian species as referable to *Phacopina* (e.g. *Ph. anceps* Clarke, *Ph. correlator* Clarke, and *Ph. nylanderi* Clarke), though at an earlier date[3] he put *Ph. correlator* into the genus *Phacopidella*. According to Clarke probably all the Devonian representatives of *Acaste* in the northern region belong to it, and Dienst[4] has referred the Coblenzian *A. schmidti* Richter to it. The South American species described as *Acaste devonica* Ulr.[5] is certainly referable to it, as Kozlowski (1923, p. 49, pl. iv, figs. 7–14) has maintained, and probably *A. convexa* Ulr.,[6] *A. acutilobata* Knod,[7] and *A. lombardi* Kozl.[8] also belong to it, all of which occur in the Devonian of the same austral region. A new species has recently been referred to *Phacopina* (*Ph. hiemalis* Reed, 1925, p. 159, pl. x, fig. 8, pl. ix, fig. 12 ?) from the Bokkeveld Beds of South Africa, of which the supposed pygidium (fig. 12) much resembles that from Bolivia attributed by Kozlowski to *A. devonica* (1923, pl. iv, figs. 13, 13*a*).

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[1] Clarke, *Archiv. Mus. Nac. Rio de Janeiro*, vol. ix, 1890, p. 15, t. i, figs. 1, 2.

[2] McLearn, *Ottawa Naturalist*, vol. xxxii, 1918, p. 33.

[3] Clarke, *Mem.* 9 *New York State Mus.*, pt. i, 1908, p. 226.

[4] Dienst, *Jahrb. k. preuss. geol. Landesanst.*, xxxiv, Heft 1, 1914, p. 545.

[5] Ulrich, *Neues Jahrb. f. Miner. Geol.*, Beil. Bd. viii, 1893, p. 21, t. 1, figs. 14*a*, *b*, 15. Kozlowski, *Annales de Paléont.*, xii, 1923, p. 49, pl. iv, figs. 7–14.

[6] Ulrich, op. cit., 1893, p. 16, t. 1, figs. 9–11; Knod, *Neues Jahrb. f. Miner., Geol.*, Beil. Bd. xxv, 1908, p. 499, t. xxi, fig. 4.

[7] Knod, op. cit., 1908, p. 497, t. xxi, figs. 5, 5*a*, 5*b*, t. xxxi, fig. 5.

[8] Kozlowski, *Annales de Paléont.*, viii, 1913, p. 14, pl. iii, figs. 7, 7*a*, *b*.

(13) *Adastocephalum.* Mitchell, 1919, *Proc. Linn. Soc. New South Wales*, 1919, vol. xliv, pt. ii, p. 446.

Type-species: *Adastocephalum teleotypicum* Mitchell, op. cit., p. 447, pl. xvi, figs. 1, 2. Lower Devonian ? Bowning, New South Wales.

This new genus is defined as follows: "Glabella subquadrate, mildly rounded in front, sides straight, only gently converging to the neck ring; lateral glabellar furrows and lobes absent. The outstanding features of this new type are the complete absence of glabellar furrows and lobes; the small convergence of the axial furrows posteriorly, squat condition of the eyes and mild convexity of the cephalon." Mitchell thinks that "perhaps the nearest relatives are *Ph. logani* Hall, *Ph. rana* Green, and *Ph. nylanderi* Clarke. But it is more like *Trimerocephalus*, in which the obsolescence of the glabellar furrows has been carried to the extreme limit, judging from Mitchell's figures, which show a rhomboidal glabella much like *Tr. laevis*. The value of this new genus may be seriously questioned. Kozlowski's subgenus *Dereimsia* (see below) is also characterized by the absence of lateral furrows on the glabella, but the latter is exceptionally inflated, and Mitchell's species cannot be included in the same subgenus, and more probably belongs to one of the Richter's new subgenera of *Phacops* named *Nephranops* or *Cryphops*, if not to *Trimerocephalus*.

(14) *Bouleia.* Kozlowski, 1923, *Annales de Paléont.*, xii, pp. 31, 56 pl. vi, figs. 7, 8.

Type-species: *Phacops dagincourti* Ulrich (*Palaeoz. Verstein. aus Bolivien, Neues Jahrb. f. miner. Geol.*, 1892, Beil. Bd. viii, p. 23, t. i, figs. 16*a–c*. Lower Devonian, Bolivia).

Kozlowski describes *Bouleia* as a subgenus of *Phacops*, stating that it is distinguished by its anterior and middle glabellar lateral furrows being perfectly developed in the manner of *Dalmanites*, although by the sum total of its characters it is clearly attached to *Phacops*. It must be also specially noted that the infra-marginal border of the head-shield is furnished with a row of short conical teeth projecting downwards and diminishing successively in size to the genal angles which are devoid of points, but are subacute. The glabella itself is a rounded semi-ellipsoid, very much swollen and inflated, and is broader than long. The thorax of the type-species has rather unusual pleurae, for each consists of a narrow depressed anterior band and a very prominent rounded broader posterior band; the tips of the pleurae form a "bizeau aigu", directed backwards. The coarse ornamentation of large tubercles on the glabella is also present in the cheeks and apparently on the posterior band of each thoracic pleura. The pygidium has the usual semicircular rounded shape and characters of *Phacops* sens. str. Kozlowski regards the subgenus as one of the most specialized forms of *Phacops*, and prior to his work Clarke [1] had referred to the type-species as a peculiar austral form which had developed a row of spines about the margin of the head of which no parallel development is elsewhere known in the genus *Phacops*.

It is probable that *Bouleia* is represented in the Lower Devonian of South Africa, and a species *Ph.* (*Bouleia* ?) *sharpei* Reed (1925, p. 161, pl. ix, fig. 6, pl. x, fig. 9), has been founded on two fragmentary pygidia resembling the type-species from Bolivia.

(15) *Dereimsia.* Kozlowski, 1923, op. cit., pp. 32, 56.

The type-species of this new subgenus is a new species *Ph.* (*Dereimsia*) *sphaericeps* Kozlowski (1923, p. 56, pl. vi, figs. 9, 9*a*, *b*), from the Lower Devonian of Bolivia. It is founded on a head-shield, and its author considers it to be the most extreme stage in the evolution attained by this group. It has an exceptional inflation of the glabella, which is hemispherical and coarsely tuberculated, and there is a complete absence of lateral furrows and of the "anneau intercalaire", but a large neck, corresponding (according to Kozlowski) to the region between the posterior lateral furrows of the glabella and the meso-occipital furrow, separates the glabella from the neck-ring, and it is marked by a pair of deep lateral pits. The facial suture is said to end at the genal angle, not in front of it. The thorax and pygidium are unknown. No other representative of this strange subgenus has been described.

(16) *Dianops.* R. and E. Richter, 1923, *Senckenbergiana*, Bd. v, Heft 3–4, August, 1923, p. 137.

The type of this subgenus or genus is *Ph. limbatus* Reinh. Richter, 1848,[2] from the Upper Devonian of Germany, and the Richters also refer to it the species *Ph. anophthalmus* Frech., *Ph. typhlops* Gürich, and *Ph. griffithides* R. and E. Richter. The characters have been restated recently by the Richters (op. cit., 1926, p. 185), and may be summarized as follows: Glabella inflated, not overhanging; marginal furrow situated below; doublure broad; lateral angles truncate. Axial furrows concave outwards. Lateral furrows obsolescent, especially the middle pair. Basal lobes not united across the middle. Facial suture marginal. Eyes absent. Border widening at posterior angles of cheeks and marginal furrow here becoming weak. Pygidium rather more than twice as broad as long; anterior margin angulated at fulcrum; surface strongly arched transversely; axial furrows not defined and segmentation indistinct. Most palaeontologists have included all such forms in *Trimerocephalus*, and it seems difficult to separate them. Thus Gürich included his *Ph. typhlops* in *Trimerocephalus*. The chief diagnostic feature seems to be the marginal course of the facial sutures and the absence of eyes. *Typhloniscus*[1] is probably allied, but has the lateral furrows on the glabella well developed (see below).

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[1] Clarke, *Mem.* 9 *New York State Mus.*, pt. i, 1908, pp. 132, 155.

[2] Reinh. Richter, "Beitr. Paläont. Thuringerwaldes": *Die Grauwacke bei Saalfeld*, i, Fauna, pp. 21–2, t. ii, figs. 18, 19 (non figs. 20, 21).

(17) *Acastella*. Reed, 1925, Geol. Mag., Vol. LXII, No. 728, p. 73, Pl. II, Figs. 4, 4*a*.

The type-species *Ph.* (*Ac.*) *macrocentrus* sp. nov. has recently been described by the author from the Wenlock Limestone, and the subgenus is based on the character of the pygidium, which has a small number of segments, simple pleurae ending inside a definite border, and possesses an elongated (upturned) mucro, as in *Anchiopella*. It is probable that the subgenus is also represented by a species from the Bokkeveld Beds of South Africa, which the author has described as *Dalmanites* (*Acastella* ?) *pseudoconvexus* sp. nov.[2] The so-called *Acaste spinosa* Salter,[3] which is thought to be identical with *Dalm. heberti* Gosselet, is a characteristic Silurian representative. It is probable that the so-called *Cryphaeus atavus* Schmidt,[4] from the Siegen Beds, belongs to this new genus, and it has been suggested that the Upper Silurian species from Canada, *Dalmanites logani* Hall, may be better included in it than in *Dalmanitina* as McLearn[5] holds. Wedekind in 1911[6] briefly referred to a group of species which had not so far been separated off as a subgenus, though they seem to deserve this rank as much as some of the others. These species comprise *Ph. granulosa* Ang., and *Ph. breviceps* Ang., from the Upper Silurian of Gotland, and they have the posterior lateral furrows of the glabella not meeting in the middle line and the two other lateral furrows relatively strong. The posterior angles of the head-shield are produced into short spines in *Ph. breviceps*, and probably so in the other species. The glabella is club-shaped and projects considerably over the frontal border in *Ph. breviceps*, but in *Ph. granulosa* to a less extent. In *Ph. breviceps* the eyes are near the glabella and far forward, but in *Ph. granulosa* they are in the middle of the cheeks. Wedekind (op. cit., 1914, t. xv, pp. 5, 7) figured two species from the Kellerwald (Upper Silurian) which he considered morphologically to correspond with *Ph. breviceps* Ang. These he named *Ph. pompeckji* (fig. 7) and *Ph. elegantulus* (fig. 5); both have short genal spines, as in the Gotland species. In 1914 (p. 42), however, Wedekind took *Ph. pompeckji* and *Ph. breviceps* as types of two different groups of

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[1] Salter, *Trans. Geol. Soc.*, ser. II, vol. vii, 1856, p. 221, pl. xxv, fig. 14. Lake, *Ann. S. African Mus.*, vol. iv, pt. iv, 1904, p. 213, pl. xxv, figs. 8, 9. Reed, ibid., vol. xxii, 1925, p. 162.

[2] Reed, *Ann. S. Afr. Mus.*, vol. xxii, 1925, p. 137, pl. ix, figs. 8, 9 ?

[3] Barrois and others, *Mém. Soc. Géol. Nord.*, vol. vi, pt. ii, fasc. 2, 1920, pl. xv, figs. 6, 7; p. 160, pl. xvii, figs. 1, 2.

[4] Schmidt, *Zeitschr. deut. geol. Gesell.*, Bd. lix, 1907, Monatsber, No. 1, p. 9, ext-figs.

[5] McLearn, *Mem.* 137 *Geol. Surv. Canada*, 1924, p. 167, pl. xxvii, figs. 3–6.

[6] Wedekind, *Zeitschr. deut. geol. Gesell.*, lxii.

Phacops sens. str. as represented in the Upper Silurian of the Kellerwald. It should be remembered that Lindström[1] in 1885 put *Ph. breviceps* Ang.[2] as a synonym of *Ph. downingiae* Murch., and used the latter specific name for the specimens from Gotland. But the presence of genal spines in *Ph. breviceps* and its allies suggests that they belong rather to the subgenus *Acastella*. (*Ph. breviceps* Barr. and *Chasmops breviceps* (Hall) are quite distinct.)

(18) *Josephulus*. Warburg, 1925, *Bull. Geol. Instit. Upsala*, vol. xvii, 1925, p. 408, pl. xi, fig. 21.

Genotype: *J. gracilis* Warburg.

This genus has been recently established by Warburg for reception of a small cranidium from the Leptaena Limestone of Sweden which is supposed to show affinities with *Pterygometopus* and *Chasmops* and therefore is placed in the *Phacopidae*. Warburg describes the single specimen in great detail, but to the present author it appears hardly to warrant a new generic name, as its characters are insufficiently known.

(19) *Nephranops*. R. and E. Richter, 1926., *Trilob. d. Oberdev., Abh. preuss. geol. Landesanst.*, N.F., Heft 99, 1926, p. 148, t. 8, fig. 48, t. 9, fig. 49, 50.

Type: *Ph. incisus* Roemer, 1866.

This Upper Devonian subgenus is characterized by the marginal furrow not being near the front end of the head-shield, but subcranidial and some distance behind and below it, so as to leave a broad band between the facial suture and itself (R. and E. Richter, op. cit., p. 127, text-fig. 15*d*); the palpebral lobe is preserved, though the eyes themselves may be gone. The pygidium is large in comparison with the head.

The Richters give the following definition: "Verschlussfurche der Saumfurche (= Naht) an der Stirn nicht genähert. Zwischen beiden Furchen bleibt also ein breiter, mitunter wulstiger Schalenstreifen (Saum). Augenverkümmerung erfolgt uber die Nierenform ; der Nierenform der Sehfläche und der Erhabenheit des Augendeckels bleiden nicht nur bei weitgehender Verkleinerung erhalten (*ocellatus miserrimus*), sondern auch nach völliger Erblindung (*incisus*) verbleibt der Augendeckel als grosse nierenförmige Schwiele Schwanz ziemlich gross, mit schwachen Gepräge."

(20) *Cryphops*. R. and E. Richter, op. cit., 1926, p. 157.

Type: *Ph. cryptophthalmus* Emmr., 1844.

This subgenus has the lower side of the head-shield as i *Trimerocephalus* sens. restr., but the reduction of the eyes is peculiar very few lenses being present, and the visual surface has a elliptical shape with a circumscribing base. The pygidium is very small and short. This is the group which Gortani (see above) termed *Microphthalmus*. The peculiar character of the eyes seems to be the chief claim for its institution.

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[1] Lindström, *Ofvers. k. vet. Akad. Förhandl.*, 1885, No. 6, p. 42.
[2] Angelin, *Palaeont. Scand.*, 1854, p. 12, t. ix, fig. 4*a*.

The definition of this new subgenus is given by its authors as follows: " Unterseite des Kopfes (Verschlussfurche, Saum) wie bei *Trimerocephalus* gebaut. Die Verkümmerung der Augen geschieht auf dem Wege, das die Sehfläche elliptisch, also gegen innen konvex begrenzt wird und dass der Augendeckel sich einebnet (*cryptophthalmus*—Tracht). Schwanz sehr klein, sehr breit und kurz." In addition to the type-species *Ph. acuticeps* Kayser and *Ph. tripartitus* Ivor Thomas are examples of this subgenus.

(21) *Comura*. R. and E. Richter, op. cit., 1926, p. 223.

Type: *Asteropyge cometa* Richter, 1909.

This Devonian subgenus has the head-shield built on the same plan as *Asteropyge stellifer* Burm., which is the type of *Metacanthus*. The pygidium has five pairs of marginal spines of great length, and the tip is produced into a spine. The ribs are inclined to form nodes at the base of the spines. We may doubt if these characters are of subgeneric rank and sufficient to separate the species from *Metacanthus* as re-established by the Richters. Indeed the latter seems to have been regarded as of little value since Barrande rejected it (see sequel).

The Richters define *Comura* as follows: " Kopf nach der Bauplan von *A.* (*Metacanthus*) gebaut. Schwanz mit 5 paarigen Anhangen von über mässiger Länge (doppelt und noch länger als die zuhörigen Rippen) und stachliger Form. Endanhang ebenfalls stachelförmig. Die Rippen neigen dazu (je nach der Art) an der Wurzel der Anhänge Knoten zu bilden. Gepräge überhaupt scharf." A figure of another species *A.* (*Comura*) *helios* R. and E. Richter (op. cit., p. 223, t. 12, figs. 37–9) is given by these authors.

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Further Note on the Age of the Rocks around the Teifi Estuary.

By J. Challinor, M.A., F.G.S., University College of Wales, Aberystwyth.

In 1925 my friend Mr. M. P. Latter[1] published in this magazine a short paper on the rocks in the neighbourhood of Cardigan. I was interested in these rocks at the time he was working on them, and in his absence abroad I have recently paid a few brief visits to this region; and it may be desirable to place on record such supplementary facts and inferences as have been obtained.

As is well known, the Ordovician and Silurian rocks as a whole in Central Wales are characterized by monotonous lithology and complex structure, and it is only the discovery of well-preserved graptolites, and the recognition of their value in zoning, that has enabled the rock succession and structural details to be unravelled in certain regions. This monotony and this complexity dominate the geology here, and although abundant graptolites occur at some localities near Cardigan, they are not well enough preserved to allow the species to be identified with certainty. Indeed, it is a region which, except for the suggestive references by Professor Jones[2] and some notes by Keeping,[1] has remained (and still remains) almost unexplored geologically.

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[1] M. P. Latter, Geol. Mag., LXII, 1925, p. 187.
[2] O. T. Jones, *Q.J.G.S.*, lxviii, 1912, p. 328.

As shown by Mr. Latter, the rocks in which graptolites occur form the lower of two well-defined groups in this region. Lithologically they are black shales, often cleaved, with bands of grit or even conglomerate. Traces of crinoids and small brachiopods occur in these grit bands. The upper series is a very uniform group of pale grey mudstones with characteristic dark mottling—these rocks are always well cleaved and often form good slates as at Cilgerran and Glogue. So far, no fossils have been found in this upper mottled group, the graptolites recorded by Professor Jones near Newcastle Emlyn and Penbryn being probably from the overlying fossiliferous shales, which appear to belong to the zone of *Dicellograptus anceps*. The boundary between the two groups is difficult to trace in detail, but can be detected with comparative ease in the immediate neighbourhood of Cardigan and St. Dogmells, as here there are many exposures. The junction is well seen in Cwm Degwel, about ½ mile S.S.W. of St. Dogmells Church, where typical black shales with grit bands pass into the typical mottled series; the beds are nearly vertical. From here the boundary trends eastwards for a mile as far as Cardigan bridge, and then swings round to a north-westerly direction, reaching the estuary in about a mile and passing along it out to sea. Westwards from Cwm Degwel it lies between Moylgrove and Monington, and then appears to curve southward, passing near Eglwyswrw. The two series can be seen in the river valley east of Crymmych Arms; quarries in the mottled slates occurring on the north side of the valley, and black shales (with graptolites) on the south and west side from Crymmych Arms at least as far as Llanfrynach. This generalized boundary, with its broad curves, is an expression of the major pitching folds of the area; if the boundary could be traced exactly it would no doubt show minor curves expressive of minor orders of pitching folds. Even the large curves above outlined are possibly themselves components of a still larger order. The general trend of pitch in this part of Wales is towards the E.N.E.

The investigation of the Ordovician rocks of the northern part of Central Wales throws light on those farther south. Some of the rock groups recognized in the north appear to be thicker and certainly cover much wider areas in the south. The mottled slates and mudstones evidently represent the very similar Abercwmeiddaw Beds of Corris, described by Professor Pugh.[2] In South Cardiganshire this group occupies the whole of the coast from the Teifi Estuary to Traethsaith, where it is followed by the uppermost Bala Beds recently described by Miss Hendriks.[3] Along this part of the coast, and for some miles inland, the rocks appear to strike in a north and south direction. East and south of Cardigan they occur as far as Newcastle Emlyn and Glogue. The lower group, the black shales with grits, is the greatly thickened representative of the Nod Glas beds of Corris and probably includes the time equivalent of the upper part of the Ceiswyn Beds—these latter, or the lower part of them, appear to be matched by Reed's "Bala and Upper Llandeilo" of Newport (Pembrokeshire). The graptolites have the same general appearance as those of the Nod Glas beds. The most prolific fossil locality so far discovered in the neighbourhood is in the bank of the Teifi at St. Dogmells, just east of the confluence of the Degwel stream with that river; and here the graptolites are in a rather better state of preservation than in the other localities. *Diplograpti* and *Climacograpti* abound, and some of the specimens of the former may be identified with some confidence as belonging to the species listed in the Nod Glas assemblages as *Orthograptus calcaratus* var. *basilicus* Lapworth. The identifications (apparently of a rather tentative nature) given by Miss Elles in Mr. Latter's note, however, contain no name occurring either in Professor Pugh's or Mr. Jehu's[1] Nod Glas lists; although the chief fossil localities mentioned ((*d*) and (*e*)) are very near the new St. Dogmells locality and at about the same horizon. This lower group, like the upper, covers a large tract of country; it occupies the coast from the Teifi Estuary to Newport (magnificent fold structures may be seen in this coast section, and the rocks here have been briefly described by Dr. Matley[2]), and forms the rocks of Dinas Head between Newport and Fishguard. These are the rocks which at Dinas Head were provisionally referred to the Llandovery by Dr. Reed,[3] and their distribution between the Teifi Estuary and Fishguard is to some extent indicated on the Geological Survey Quarter-Inch Map (New Series, Sheet 13) and coloured "Llandovery"; although Keeping[4] in 1881 had already corrected the error of placing these rocks in the Silurian.

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[1] W. Keeping, Geol. Mag., XIX, 1882, p. 519.

[2] W. J. Pugh, *Q.J.G.S.*, lxxix, 1923, p. 508.

[3] E. M. L. Hendriks, Geol. Mag., LXIII, 1926, p. 121.

In conclusion, I wish to state that, while I am alone responsible for the facts and opinions contained in this paper, I have had the advantage of discussing these matters frequently with Professor Pugh.

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[1] R. M. Jehu, *Q.J.G.S.*, lxxxii, 1926, p. 465.
[2] C. A. Matley, *Birm. Nat. Hist. and Phil. Soc.*, x, 1897, p. 92.
[3] F. R. C. Reed, *Q.J.G.S.*, li, 1895, p. 149.
[4] W. Keeping, *Q.J.G.S.*, xxxvii, 1881, p. 141.

Further Jurassic Fossils from Kenya Colony.

By J. W. Gregory, D.Sc., F.R.S.

MR. E. J. WAYLAND, of the Geological Survey of Uganda, has recently found three interesting fossils which throw further light on the age of the beds to the west and north of Mombasa. One of them is a cast of an ammonite in brown ironstone, which has been kindly examined by Dr. L. F. Spath; he says that being only a cast its specific identification is perhaps impossible. It is a *Grossouvria*, and he says it is very similar to several examples of *G. lateralis* (Waagen), from the Callovian anceps beds of Kachh. He identifies it as certainly a member of Siemiradzki's form-series of *Perisphinctes balinensis*, Neumayr. This identification is of interest as the fossil was obtained at the point $\frac{10}{6}$ miles from Mombasa on the Uganda Railway. This position lies to the west of, and therefore at a lower horizon than, the ammonite-bearing shales near Mombasa. At 11$\frac{1}{9}$ miles along the railway I found a lamellibranch in some dark shales and Dacqué (*Geol. Rundsch.*, vol. i, 1910, p. 159) has recorded from near by some obscure Cephalopod and plant remains which he identified as Bathonian.

Mr. Wayland's ammonite apparently comes from an exposure which I referred to (*Geology and Rift Valleys of East Africa*, 1921, p. 63) as a shelly sandy limestone, in contact, by a possibly faulted junction, with some shales. The shell fragments, however, which I obtained at this locality were indeterminable, but from the general evidence I suggested the Callovian age of the beds at this locality. Dr. Spath's identification of the ammonite confirms this conclusion.

The two other fossils obtained by Mr. Wayland were from 1 mile west of a point 3 miles north of Freretown, which is just north of Mombasa. Both fossils are *Parallelodon*, and one of them is well-preserved. Dr. J. Weir has kindly examined them, and says that the species is *Parallelodon egertonianus*, which has previously been found in Somaliland, but has not been recorded from Kenya Colony. This fossil occurs in Somaliland at two horizons—the Meragalleh Limestone, which is Tithonian to Kimmeridgian, and a lower horizon, which is referred in the Monograph of the Hunterian Museum, i, 1925, p. 4, to the Oxfordian or Callovian. Dr. Weir, who described the specimens of *Parallelodon* collected in Somaliland by Messrs. Wyllie and Smellie (ibid., p. 91), is inclined to regard the lower horizon as rather Oxfordian than Callovian. The species is also found in India in a horizon referred to the Bathonian. From the material available Dr. Weir has not found it possible to distinguish the forms from the two Somaliland horizons. From the position of the Freretown *Parallelodon*, it is probably from the higher horizon. It is to be hoped that Mr. Wayland's discovery will encourage search for more fossils from both these positions and especially from the Callovian bed around the point $\frac{10}{6}$ miles on the Uganda railway.

Bernicia praecursor gen. & sp. nov., a Lower Carboniferous Freshwater Gastropod.

By L. R. Cox, M.A., F.G.S.

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I. Introduction.

VERY little is known of the early history of the non-marine Gastropoda; hence the discovery in the coal-bearing strata of Scremerston (Northumberland) of a small species closely resembling certain modern fluviatile operculate shells is of considerable interest. My thanks are due to Mr. J. Pringle for bringing the specimens in question to my notice; to Mr. R. G. Carruthers, to whom their discovery is due, for sending me particulars; and to Dr. F. L. Kitchin for permission to borrow them from the Museum of Practical Geology, where they are deposited.

The existing records of Palaeozoic Gastropoda, both pulmonate and operculate, have been summarized by me in a previous paper.[1] The only fluviatile operculate Gastropoda recorded from the strata of that era are all, like the species here described, of Lower Carboniferous age, and comprise "*Ampullaria*" *powelli* Walcott,[2] from the Eureka district of Central Nevada, U.S.A., *Viviparus garwoodi*, nom. mut. (= *V. carbonarius* Garwood,[3] non Roemer [4] sp.), from Ribblesdale, Yorkshire, and a supposed *Valvata* (not mentioned by me previously) referred to by C. Moore [5] as occurring in the Carboniferous Limestone of Yorkshire, but not described. It is very remarkable that no shells of this group have been found in the Coal Measures proper, either in Europe or North America.

The specimens here described were found in the core of a boring (No. 1) made in 1915 at the Greenwich Hospital Estate, Scremerston, the full details of which have recently been published in the *Geological Survey Memoir* on "The Geology of Berwick-on-Tweed, Norham, and Scremerston" (1926), pp. 36–9. The Scremerston Main Coal was met with at a depth of 335 ft. 7 in., and consisted of the following strata :—

	ft.	in.
Coal	2	6
Hard dark grey Shale		8
Dark grey Sandstone with Entomostraca . .	1	1
Foul Coal		10

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[1] *Q.J.G.S.*, vol. lxxxii (1926), pp. 405–6.

[2] *Science*, vol. ii (1883), p. 808. *U.S. Geol. Surv. Monograph*, viii (1884), p. 261.

[3] Geol. Mag., Vol. LIX (1922), pp. 289–93.

[4] *Versteinerungen des Norddeutschen Oolithen-Gebirges* (1836), p. 160 (*sub Paludina*).

[5] *Q.J.G.S.*, vol. xxiii (1867), p. 557.

	ft.	in.
Hard dark grey Limestone, with small Gastropods, pyritized Entomostraca, and Plant Impressions	1	0
Blackstone		3
Coal	2	6
Light grey Shale		

The gastropods are pyritized and the details of their sculpture beautifully preserved. The dark limestone in which they occur in abundance is extremely hard, and they can only be freed from this matrix with considerable difficulty. One specimen, described as the holotype, has, however, been extracted almost complete. There is no doubt, both from its occurrence and from its general appearance, that the limestone is a freshwater deposit.

II. Description of the New Species.

Bernicia praecursor gen. et sp. nov.

Etymology.—The genus is named after the Saxon kingdom Bernicia, which included Northumberland.

The trivial name refers to the fact that the species is a forerunner of the Hydrobiidae.

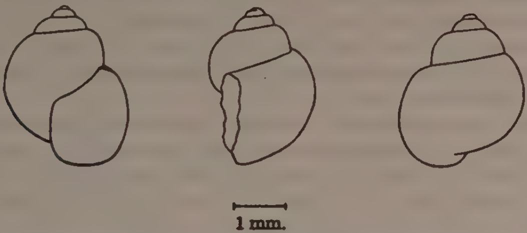

Fig. 1.—*Bernicia praecursor* gen. et sp. nov. The delicate growth-striae are not indicated in the figures.

Diagnosis.—Shell small, ovate, naticiform, the height slightly in excess of the diameter; spire low, the body-whorl occupying six-sevenths of the total height of the shell; nucleus minute; whorls four, the early ones narrow, the penultimate relatively much wider; body-whorl very large, with a narrow, rounded shoulder becoming pronounced near the aperture, and with moderately convex flanks tending to be obscurely sub-angular at the periphery, which lies below the prolongation of the last suture; base imperforate; aperture sub-rectangular rather than ovate, not appreciably oblique, occupying slightly more than half the total height of the shell; outer lip sub-vertical and flattened-convex laterally, bent round posteriorly so as to be nearly horizontal where it meets the suture; columella slightly concave; surface of shell delicately ornamented with fine growth-threads, which are nearly vertical on the flanks of the whorls, but are bent forward in the immediate neighbourhood of the sutures so as to meet the latter at an angle of about 45 degrees.

Dimensions.—Height of shell 3 mm., height of body-whorl 2·6 mm., height of aperture 1·8 mm., width of aperture 1·4 mm., diameter of shell 2·5 mm.

Material.—The holotype (Museum of Practical Geology, Z 1821) is an undistorted individual, the exterior of which is very well preserved; owing to the hard matrix no attempt has been made to develop the interior of the aperture, but, in a shell of this sort, the details of the inner lip, etc., are not likely to be of any importance. Numerous paratypes, mostly crushed examples, occur in the matrix (Z 1822).

Affinities.—The freshwater Gastropoda, both pulmonate and operculate, are well known to have been one of the most conservative organic groups, and the possibility of a genus still living having existed so long ago as Lower Carboniferous times cannot be at once dismissed. The present species immediately recalls several living genera of small shells included in the Hydrobiidae, and, even were it not known to occur in a deposit of freshwater origin, it would obviously be referable to that family. Close comparison with representatives of those recent genera which it resembles most indicates, however, that there is none to which it can undoubtedly be referred. *Amnicola* and *Pseudamnicola*, which it resembles in its small size and its general proportions, differ in possessing an umbilicus and a proportionately smaller body-whorl. *Bithynia*, besides being usually larger, has a more elevated spire. *Lithoglyphus* has a wider aperture and callous columellar lip.

On the whole, therefore, it seems preferable to place the present species in a new genus rather than group it with any living forms with which it cannot definitely be proved to be congeneric. Its discovery is of considerable importance first as constituting (apart from the less satisfactory preserved *Viviparus garwoodi*) the earliest record of a non-marine gastropod from British rocks, secondly as proving the existence in Palaeozoic times of the family Hydrobiidae, hitherto unknown from rocks older than Jurassic.

REVIEWS.

Eruptive Rocks: their Genesis, Composition, Classification and their Relation to Ore Deposits, with a chapter on Meteorites. By S. J. Shand. pp. 350, text figures 43. Thomas Murby and Co., London. Price 20*s.* net.

THIS book, so we are informed in the preface, is the outcome of "three insistent wishes": (1) "to clean up the jungle of rock names"; (2) "to make the results and conclusions of petrology intelligible to matter of fact people like physicists and chemists, who like to do their thinking in quantitative terms and who are apt to listen with indifference to the assertions of 'affinity' and 'consanguinity' that underlie so many petrographic contentions", and lastly, "to bring theory and practice together to save petrology from the reproach of being an academic study of little use in life." This threefold objective the author sets out to attain in the ensuing chapters. The first five chapters cover a wide field and treat of the nature of igneous rocks, their constituent minerals, volatile (here called fugitive) components of the magma, and the phenomena attendant upon its consolidation. The controversial subject of assimilation is not overlooked. The sixth chapter is reserved for a short discussion of existing rock classifications, and forms the prelude to the seventh, in which the author's own system of petrography is introduced. Thereafter follows the application of this system in detail to recognized rock types, the treatment being prefaced by appropriate descriptions of the mode of occurrence of the rock groups in question.

The two concluding chapters, both well presented, are reserved for meteorites and those ore deposits which owe their genesis in whole or in part to igneous magma. Naturally the author's system as expounded in chapter seven calls for most consideration. Like others, it is a mineralogical classification, but in it geological mode of occurrence is not utilized directly as a factor.

The main factors of the system are: (1) the degree of crystallization—giving two main groups—eucrystalline and dyscrystalline (= ill-crystallized) rocks, (2) the relation of silica to the bases and alumina to the bases, (3) the proportions of light and heavy minerals, (4) the percentages of the different felspars.

The relation of silica to the bases provides the triple subdivision into "undersaturated", "saturated", and "oversaturated" rocks. Rock minerals are regarded as "saturated" or "unsaturated", according as they are stable or unstable "in the presence of free silicic acid under such conditions as are realized in the magma". Assemblages of these minerals give the rock groups above-mentioned, a rock being "oversaturated" if it contains free silica.

The confusing way in which the term saturation is used will be evident from the fact that in reference to a mineral it has a chemical significance, and in reference to rocks it is employed both in a chemical and in a distinctly unusual physical sense. The two divisions of minerals contain such anomalies as an orthosilicate like biotite classed as a "saturated" mineral, while the garnet group has both "saturated" and "unsaturated" members. This crude arrangement cannot but be reflected in the rock groups themselves, for it is clear that according to the physical conditions of consolidation, some given magma may produce at one time "saturated", at another time "unsaturated" rocks. One example will suffice. A leucite-olivine assemblage is "undersaturated", while its chemically equivalent assemblage biotite-orthoclase is "saturated". The author's treatment of this saturation problem on pp. 126–30 is somewhat unfortunate. The triangular diagram of Fig. 20 shows little sign of being the equilibrium diagram it is said to be, and clarity is not gained by adding that fig. 20 is "greatly simplified" or that "no quantitative meaning" is attached to it. To make matters worse the region of the "nearly saturated rocks" is erroneously placed in the figure. The elucidation of p. 128 and of the "simplified equilibrium diagram of fig. 21" has proved beyond the capacity of the present writer.

It would be of interest to learn whether the "matter of fact" physicists and chemists alluded to in the preface will be indifferent to, or grateful for, the exposition of petrology submitted to them here. The author has roamed far and wide in the search for examples of the principles expounded and for adequately described rocks to typify the subdivisions of his system, while for illustrations he has drawn effectively from the wide spaces of South Africa, thus importing a refreshing breeze into his world of saturation. In conclusion, we may be permitted to add that the system is unlikely to supplant the present Rosenbusch classification. To-day, the search for the ideal classification is like the quest for El Dorado. Probably most petrologists will be content to make the existing systems serve their purpose, concentrating their attention rather on the accumulation of physico-chemical data from which eventually the genetic classification will arise. Towards this goal, apart altogether from experiment, we shall advance, not simply by calculating the quantitative mineralogical proportions of rocks, but rather by determining, in relation to the containing rock, the composition of those complex constituent phases which, for lack of knowledge, we group vaguely to-day as augite, hornblende, biotite, etc. The price of the book does not compare favourably with that of other recent petrological issues.

C. E. T.

THE GEOLOGY OF SAINT HELENA ISLAND. By R. A. DALY. Proc. Amer. Acad. Arts and Sci., vol. lxii, pp. 31–92, with 25 plates (Shaler Memorial Series), 1927.

A PRELIMINARY note on the results of Professor Daly's visit to St. Helena in the course of the Shaler Memorial Expedition to South Africa was published in the GEOLOGICAL MAGAZINE in 1922. The present paper is an amplification and full discussion of the data then obtained. In the wealth of material here presented it is rather difficult to select special points for comment, but certainly one of the most interesting conclusions is that the basaltic lava flows from the great centre of eruption proceeded not from a pipe in the normal text-book way, but from a vast network of fissures crossing one another at all angles and often almost or quite in contact. This seems to be a new conception in vulcanology, and is taken to indicate a condition of tension in the crust. The great majority of the lavas are quite normal basalts, much like those in other oceanic islands, but in addition there are plugs and masses of trachyte and phonolite, the usual alkaline differentiates.

The latter part of the paper is occupied by a very full and interesting discussion of the evidence for changes in the relative level of land and sea. An elevation of some 16 feet in comparatively recent times seems to be well established by rock platforms with caves at their upper limit.

The whole paper is extremely interesting and evidently very important. It will well repay careful study.

ÜBER DIE NATUR UND BILDUNGSWEISE DER MARINEN EISENSILIKATE INSBESONDERE DER CHAMOSITISCHEN SUBSTANZEN. By K. C. BERZ. Forts. d. Geol. u. Pal., Heft ii, pp. vii and 365–521, with vi plates. Berlin: Borntraeger, 1926. Price 12 mark.

IN this publication the author sets out to give a full and elaborate discussion of the origin and characters of the numerous occurrences of sedimentary oolitic iron ores that contain a notable proportion of the green iron silicate usually described as chamosite. Among other things he gives a bibliography of 148 items. When we find, however, that this bibliography contains no reference to the epoch-making work of Hayes on the Wabana iron ores of Newfoundland, we begin to wonder whether the author is as fully conversant as he thinks with the modern developments of the subject. Further, no reference is made to the second and much more important volume of Cayeux on the oolitic iron ores of France. The author lays much stress on the part played by currents in the formation of such deposits; hence his interminable discussions of deep-sea sediments do not seem to have much bearing on the matter at issue. This work cannot be considered as adding materially to our knowledge of this interesting and difficult subject.

Los Yacimientos minerales de la República Argentina relacionados con las rocas igneas de las diferentes épocas geológicas. By R. Beder. Revista de la Univ. Nac. de Córdoba, Año XIV, 1927.

THIS very interesting paper is the report of a lecture given by Dr. Beder at Córdoba in 1926, with some amplifications. He begins by pointing out that petrology and mineralogy have not hit the public fancy to the same extent as the biological sciences, but nevertheless they are of the greatest importance from many points of view. He whole-heartedly supports modern views on the close connexion between ore-deposit and igneous rock-formation, which he divides into three phases, liquid-magmatic, pegmatitic-pneumatolytic, and hydrothermal. The rest of the lecture is occupied by a detailed account of the periods of igneous activity and their concomitant ore-deposits in the Argentine Republic, forming an exceedingly useful summary of this large subject.

The penultimate paragraph contains so much good sense that it is worth translating.

"In this exposition I have tried implicitly to bring into relief the connexion between the theoretical science of mineralogy with its kinsman petrography, and the applied science of mining. Neither of them can prosper without the constant collaboration of the other. Mineralogy and petrography will always maintain their contact with mining on account of its effective participation in the accumulation of our empirical knowledge, while on the other hand the miner, the technician, like the financier of to-day, know how to appreciate the value of theoretical ideas, which enable them to avoid the disagreeable surprises that sometimes overtake those whose education has been guided purely by rule of thumb methods."

A Text-book of Mining Geology. By James Park. pp. viii + 376, with 91 figures. Fifth edition. London: C. Griffin and Co, 1927. Price 12*s*.

IT is not customary to review at length new editions of well-known books, but it may be well to point out that in this, the fifth edition, the author has made a good many changes in order to bring it up to date. His views on the origin of ore-deposits and their relation to igneous activity are quite modern, but it may perhaps be suggested that he is not fully acquainted with some of the later writings on the ores of the British Isles; at any rate he does not refer to them. But the book will be of considerable value to students who desire to acquire some knowledge of the economic minerals of the world from the point of view of a mining authority of wide experience. The last twenty pages give a useful sketch of the practical procedure in the examination and valuing of mines.

REPORTS AND PROCEEDINGS.

GEOLOGISTS' ASSOCIATION.

Friday, 10*th June*, 1927.

"Echinoid Illustrations of some Problems in Evolution." By Professor H. L. Hawkins, D.Sc., F.G.S.

A discussion of some of the aspects of phylogeny and morphogeny (such as the persistence of root-stocks, variation in rate of evolution, mutations and saltations, adaptation and the influence of environment, orthogenesis and the causes of extinction) as illustrated by the palaeontological record of the Sea-Urchins.

"The Lower Carboniferous Succession in the Westmorland Pennines and the Relations of the Pennine and Dent Faults." By J. Selwyn Turner, B.Sc., F.G.S.

The Lower Carboniferous succession is described in detail. The conglomerates of Roman Fell are tentatively referred, together with the Polygenetic Conglomerate, to the Devonian. Marine beds of pre-*N. minus* age do not occur north of Roman Fell. South of that hill the lithological boundaries transgress the time horizons. The oldest marine deposits are of *Seminula gregaria* age and are succeeded by *Michelinia grandis* beds. A small-non-sequence is recorded from the base of D_1. *Orionastraea* is recorded in situ for the first time in Westmorland from the Tyne Bottom and Single Post Limestones. An algal horizon with *Cyathaxonia* occurs at the top of the Scar Limestone.

By means of sections across the Pennine Faults it is shown that in pre-New Red times the Inner Pennine Fault came into existence. From the area between Brough and Kirkby Stephen it is shown that the Dent Fault is of the same age. By means of these the Vale of Eden was elevated above the Rigid Block to the east. The Brockrams are considered to have been derived from the Howgills and the Lake District and not from the Pennine Fault-scarp, which is post-New Red.

In post-New Red, probably early Tertiary time, thrusting carried up the *M. grandis* beds at Brough, so that they now rest against D_1 beds. The Roman Fell beds were also thrust up on to D_1. Folding of the Carboniferous also took place further north along the Pennine scarp. Subsequently the Outer and Middle Pennine Faults were initiated, dropping the Vale of Eden below the level of the Rigid Block and leaving the Cross Fell Inlier to be subsequently exposed as a horst.

CORRESPONDENCE.

KATA-METAMORPHISM OR HYPO-METAMORPHISM?

Sir,—Van Hise, in his monumental work "A Treatise of Metamorphism" [Monograph XLVII, *United States Geological Survey* (1904), p. 43], recognizing the important influence of depth below the surface in determining the character of the alterations of rocks, classifies metamorphism into (1) alterations in the zone of katamorphism, and (2) alterations in the zone of anamorphism. The *zone of katamorphism* he defines as the zone in which the alterations of rocks result in the production of simple compounds from more complex ones. This zone, which is, of course, that lying nearer the surface, he subdivides into the belt of weathering, which extends from the surface to the level of ground water, and the belt of cementation, which extends from the ground-water level to the zone of anamorphism. The *zone of anamorphism* is defined by Van Hise as the zone in which the alterations of rocks result in the production of complex compounds from more simple ones. It is, therefore, the lower zone, and it extends from the base of the belt of cementation to as great depths as metamorphic effects extend. Briefly, the zone of katamorphism is that in which compounds are broken *down*, and the zone of anamorphism is that in which they are built *up*. In his use of these prefixes *kata* and *ana*, Van Hise is guided by the analogy with the biological terms katabolism and anabolism (l.c., pp. 162 and 169), and the selection of these prefixes is clearly a good one.

From the physico-chemical point of view, the distinction between these two zones is of fundamental importance, and these distinctions may be summarized in the following quotation (l.c., p. 186) from Van Hise:—

> "In conclusion of this part of the subject it may be said that in the zone of katamorphism the alterations are mainly controlled by the chemical law that reactions take place with liberation of heat, and this ordinarily results in increase of volume, provided the compounds which form remain as solids. In the zone of anamorphism the reactions are mainly controlled by the physical law that reactions take place with decrease of volume, and this commonly results in chemical reactions with absorption of heat. In the upper zone chemical law is the determinative factor in the reactions; in the lower, physical law. In the upper zone the important chemical reactions are those of oxidation, carbonation (involving desilication), and hydration; in the lower zone the important reactions are those of deoxidation, silication (involving decarbonation), and dehydration. In the upper zone

the minerals are few in number, of low specific gravity, and probably of simple molecular structure; in the lower zone the minerals are numerous, of high specific gravity, and probably of complex molecular structure."

These two terms katamorphism and anamorphism are clearly of the greatest use to geologists, and with their introduction, Van Hise proposed terms that have done much to stimulate clear thinking in the realm of the geology of metamorphic rocks. It is most desirable, therefore, that terms of such use, and with such a wealth of connotation, should not have their meanings obscured by subsequent use with a different meaning, either in their substantive or their adjectival form.

It is particularly to be regretted therefore that Grubenmann should have used the term Katametamorphose in a sense completely opposed to the meaning of the katamorphism of Van Hise. In his stimulating work *Die Kristallinen Schiefer*, of which the first or general part was published in 1904, and the second or special part in 1907, Grubenmann classifies the crystalline schists into twelve groups, based upon chemical composition; the members of each group he classifies into three divisions known as Epi-Gesteine, or epi-rocks, characteristic of the uppermost zone of metamorphism, meso-rocks, characteristic of the middle zone, and kata-rocks, characteristic of the deepest zone. Grubenmann does not in the first edition of his work actually use the phrases epi-metamorphism, meso-metamorphism, and kata-metamorphism, but in the third edition (*Die Gesteinsmetamorphose*, by Grubenmann and Niggli, 1924, i, pp. 374–5) the terms epi-zone, meso-zone, and kata-zone, and epi-metamorphism, meso-metamorphism, and kata-metamorphism, of course in their German form, are used. We observe, therefore, that a rock in passing from Grubenmann's uppermost or epi-zone to his lowermost or kata-zone would be undergoing the anamorphic changes of Van Hise, whilst rocks passing from the deepest or kata-zone of Grubenmann in the direction of the uppermost or epi-zone, would be undergoing the katamorphic changes of Van Hise.

This use of the prefix *kata* in two such diametrically opposed senses by these two different authors makes it difficult for students of metamorphic geology to use these terms at all. It is, therefore, fortunate that Grubenmann does not use the prefixes *epi*, *meso* and *kata* until the second part of his original work (compare page 60 of part i with page 172 and 21 of part ii), so that clearly priority in the use of the prefix *kata* belongs to Van Hise. Further, it may be noted that the date of Van Hise's letter of transmittal to the Director of the United States Geological Survey of the manuscript of his treatise is 30th April, 1903, whereas the date attached to the preface of part i of Grubenmann's treatise is June, 1904.

Therefore, it seems desirable to find a substitute for the prefix *kata* when applied to the lowest of Grubenmann's three zones.

Epi and *meso* are primarily prefixes of position, whereas *kata* carries with it more the implication of movement or change, and was not, I suggest, the proper prefix to select even if it had not been already pre-occupied. *Hypo* appears to be the more suitable prefix for *under*, and if we re-name Grubenmann's kata-zone as the *hypo-zone* and speak of *hypo-metamorphism* in the sense in which he and Niggli use the term kata-metamorphism, we shall be introducing desirable clarity into the nomenclature of metamorphism. I suggest, therefore, that writers upon metamorphic geology who have occasion to refer to the different zones of metamorphism should use katamorphic (or kata-metamorphic) in the sense proposed by Van Hise, and hypo-metamorphic (or hypomorphic) in the place of Grubenmann and Niggli's kata-metamorphic. As a parallel example of the use of the prefix *hypo* in conjunction with *epi* and *meso*, it is perhaps not out of place to point out to users of Becke's nomenclature as applied to the description of structures of metamorphic rocks, that biologists have a parallel trio in which the prefixes *epi*, *meso*, and *hypo* are used as prefixes of position, viz., *epiblast*, *mesoblast*, and *hypoblast*.

L. L. Fermor.

Geological Survey of India,
Calcutta,
9th June, 1927.

THE HOLYWELL SHALES AND "BLACK LIMESTONE" OF NORTH FLINTSHIRE.

Sir,—Will you kindly allow me space to correct an error in my paper appearing in your last issue.

On page 259, last paragraph, first line, the *western* boundary of the Chert Beds is described as the " eastern ".

H. C. Sargent.

14th June, 1927.